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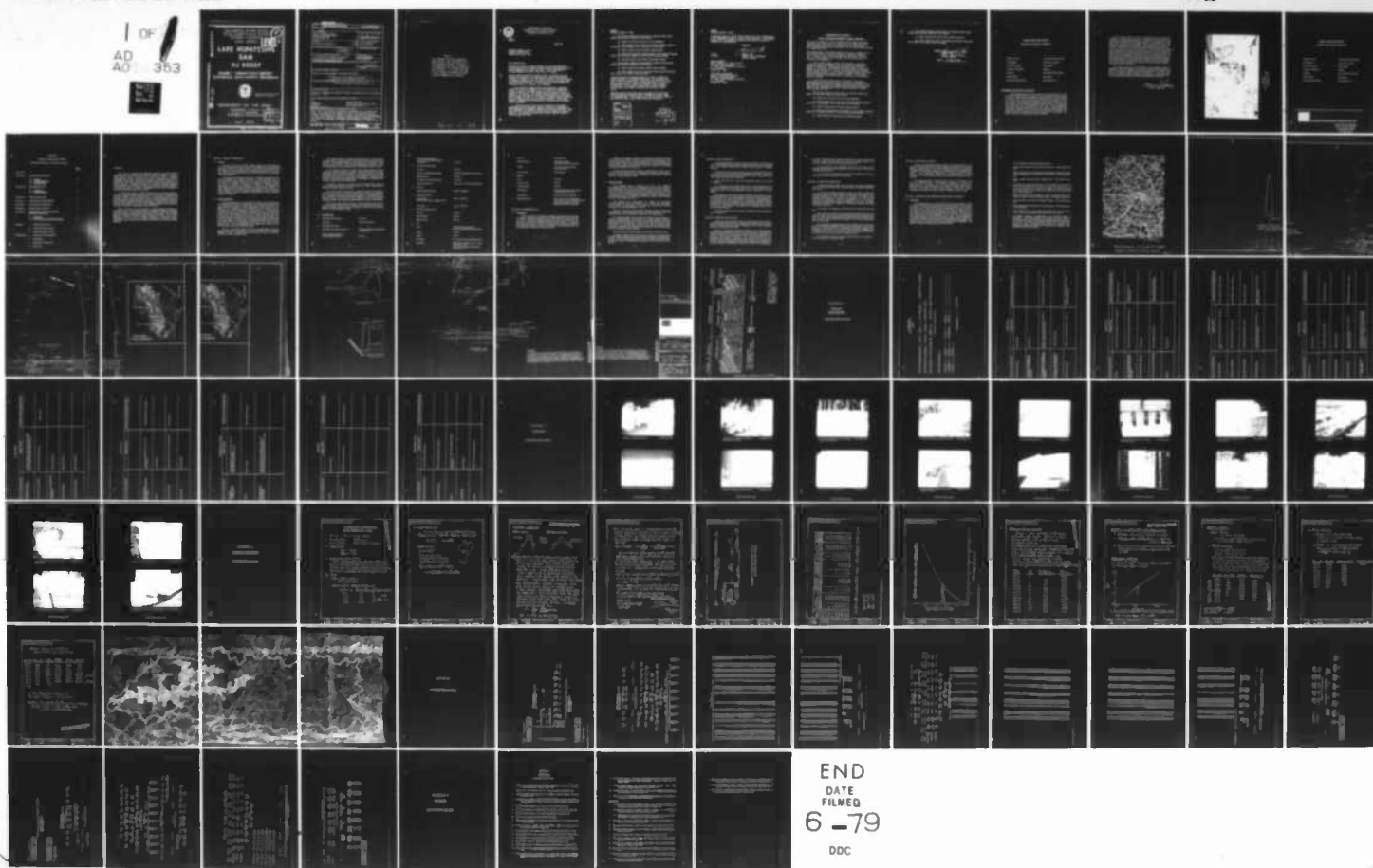
NEW JERSEY STATE DEPT OF ENVIRONMENTAL PROTECTION TRENTON F/G 13/2
NATIONAL DAM SAFETY PROGRAM. LAKE HOPATCONG DAM (NJ00327), DELA--ETC(U)
APR 79 D J LEARY

DACW61-78-C-0124

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DELAWARE RIVER BASIN
MUSCONETCONG RIVER
MORRIS COUNTY
NEW JERSEY



LEVEL

LAKE HOPATCONG DAM

NJ 00327

**PHASE 1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM**

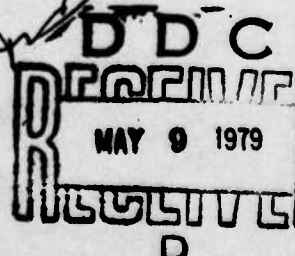
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DEPARTMENT OF THE ARMY

Philadelphia District
Corps of Engineers
Philadelphia, Pennsylvania



April, 1979

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report cites results of a technical investigation as to the dam's adequacy. The inspection and evaluation of the dam is as prescribed by the National Dam Inspection Act, Public Law 92-367. The technical investigation includes visual inspection, review of available design and construction records, and preliminary structural and hydraulic and hydrologic calculations, as applicable. An assessment of the dam's general condition is included in the report. | | |

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**DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
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PHILADELPHIA, PENNSYLVANIA 19106**

2 MAY 1979

**Honorable Brendan T. Byrne
Governor of New Jersey
Trenton, New Jersey 08621**

Dear Governor Byrne:

Inclosed is the Phase I Inspection Report for Lake Hopatcong Dam in Morris County, New Jersey which has been prepared under authorization of the Dam Inspection Act, Public Law 92-367. A brief assessment of the dam's condition is given in the front of the report.

Based on visual inspection, available records, calculations and past operational performance, Lake Hopatcong Dam, a high hazard potential structure, is judged to be in fair overall condition. The dam's spillway is considered inadequate since 67 percent of the Probable Maximum Flood (PMF) would overtop the dam. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980. In the interim, a detailed emergency operation plan and warning system, should be promptly developed. Also, during periods of unusually heavy precipitation, around-the-clock surveillance should be provided.

b. Within six months from the date of approval of this report, engineering studies and analyses should be initiated to determine the dam's embankment and foundation condition and structural stability. This should include test borings to determine material properties relative to stability. Any remedial measures found necessary should be initiated within calendar year 1980.

NAPEN-D

Honorable Brendan T. Byrne

c. The following remedial actions should be completed within three months from the date of approval of this report:

- (1) Remove all trees from the area of the embankment.
- (2) Repair eroded areas of the dam and provide upstream riprap on the slope of the embankment at the right side of the spillway.
- (3) Repair cracked stairs and remove vegetal growth.
- (4) Repair the deteriorated right sidewall of the spillway discharge channel and the asphalt pavement of the fountain discharge channel.
- (5) Clean and install trash racks in gatehouse forebays.

d. The following remedial actions should be completed within twelve months from the date of approval of this report:

- (1) Repair spalled and cracked concrete where necessary.
- (2) Check condition of water level gages below present lake level and if found to be rusted, replace the gages.

A copy of the report is being furnished to Mr. Dirk C. Hofman, New Jersey Department of Environmental Protection, the designated State Office contact for this program. Within five days of the date of this letter, a copy will also be sent to Congressman James A. Courter of the Thirteenth District. Under the provisions of the Freedom of Information Act, the inspection report will be subject to release by this office, upon request, five days after the date of this letter.

Additional copies of this report may be obtained from the National Technical Information Services (NTIS), Springfield, Virginia 22161 at a reasonable cost. Please allow four to six weeks from the date of this letter for NTIS to have copies of the report available.

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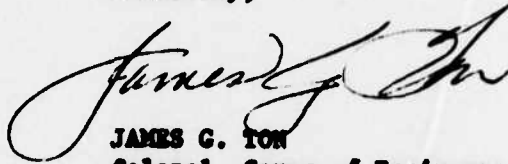


HAFEN-D

Honorable Brendan T. Byrne

An important aspect of the Dam Safety Program will be the implementation of the recommendations made as a result of the inspection. We accordingly request that we be advised of proposed actions taken by the State to implement our recommendations.

Sincerely,



**JAMES G. TON
Colonel, Corps of Engineers
District Engineer**

**1 Incl
As stated**

**Copies furnished:
Dirk C. Hofman, P.E., Deputy Director
Division of Water Resources
N. J. Dept. of Environmental Protection
P. O. Box CN029
Trenton, NJ 08625**

**John O'Dowd, Acting Chief
Bureau of Flood Plain Management
Division of Water Resources
N. J. Dept. of Environmental Protection
P. O. Box CN029
Trenton, NJ 08625**

LAKE HOPATCONG DAM (NJ00327)

CORPS OF ENGINEERS ASSESSMENT OF GENERAL CONDITIONS

This dam was inspected on 7 and 18 December 1978 by Langan Engineering Associates, Inc. under contract to the State of New Jersey. The state, under agreement with the U.S. Army Engineer District, Philadelphia, had this inspection performed in accordance with the National Dam Inspection Act, Public Law 92-367.

Lake Hopatcong Dam, a high hazard potential structure, is judged to be in fair overall condition. The dam's spillway is considered inadequate since 67 percent of the Probable Maximum Flood (PMF) would overtop the dam. To insure adequacy of the structure, the following actions, as a minimum, are recommended:

a. The spillway's adequacy should be determined by a qualified professional consultant engaged by the owner using more sophisticated methods, procedures, and studies within six months from the date of approval of this report. Any remedial measures necessary to insure the adequacy of the spillway and to prevent overtopping should be initiated within calendar year 1980. In the interim, a detailed emergency operation plan and warning system, should be promptly developed. Also, during periods of unusually heavy precipitation, around-the-clock surveillance should be provided.

b. Within six months from the date of approval of this report, engineering studies and analyses should be initiated to determine the dam's embankment and foundation condition and structural stability. This should include test borings to determine material properties relative to stability. Any remedial measures found necessary should be initiated within calendar year 1980.

c. The following remedial actions should be completed within three months from the date of approval of this report:

- (1) Remove all trees from the area of the embankment.
- (2) Repair eroded areas of the dam and provide upstream riprap on the slope of the embankment at the right side of the spillway.
- (3) Repair cracked stairs and remove vegetal growth.
- (4) Repair the deteriorated right sidewall of the spillway discharge channel and the asphalt pavement of the fountain discharge channel.
- (5) Clean and install trash racks in gatehouse forebays.

d. The following remedial actions should be completed within twelve months from the date of approval of this report:

- (1) Repair spalled and cracked concrete where necessary.
- (2) Check condition of water level gages below present lake level and if found to be rusted, replace the gages.

APPROVED:


JAMES G. TON
Colonel, Corps of Engineers
District Engineer

DATE:

2 May 1979

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

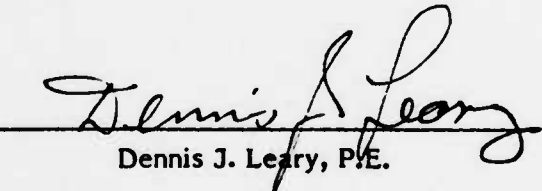
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|---------------------|--------------------|
| NAME OF DAM: | LAKE HOPATCONG DAM |
| ID NUMBER: | FED ID No. NJ00327 |
| STATE LOCATED: | NEW JERSEY |
| COUNTY LOCATED: | MORRIS |
| STREAM: | MUSCONETCONG RIVER |
| RIVER BASIN: | DELAWARE |
| DATE OF INSPECTION: | DECEMBER 1978 |

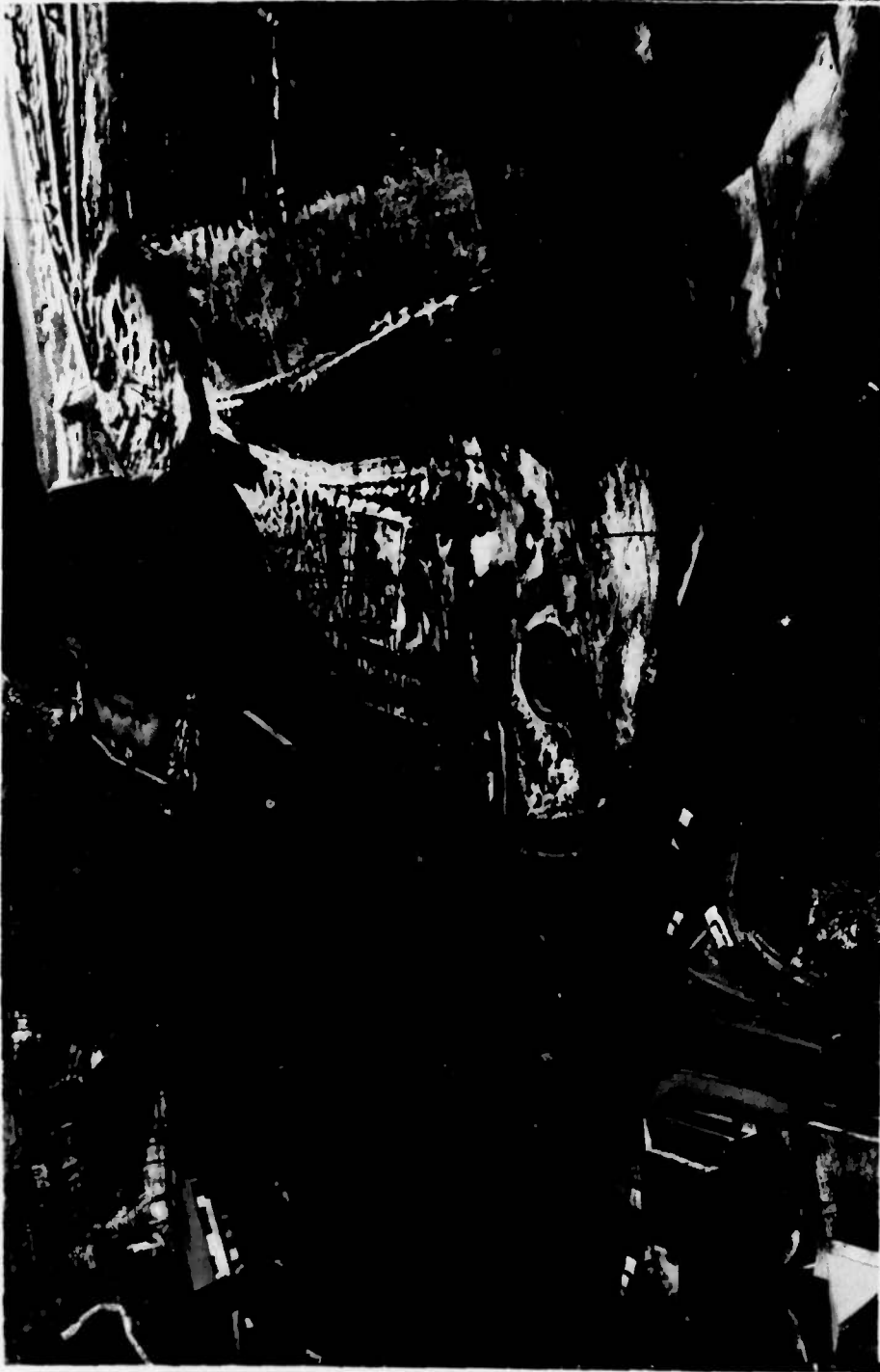
ASSESSMENT OF GENERAL CONDITIONS

Lake Hopatcong Dam is 54 years old and in fair overall condition. There are trees and brush on the downstream slope of the embankment at the right of the spillway. The concrete on the spillway and gatehouse has cracked or spalled at a few locations. The trash racks have rusted and are not in place at two of the forebays. Erosion has occurred upstream of the right embankment and at the junction of the embankment and spillway right sidewall. The stairs at the downstream side of the right embankment and at the left side of the gatehouse have cracked and there is vegetal growth in the cracks. The right sidewall of the spillway discharge channel and the fountain discharge channel asphalt have deteriorated. Sediment has accumulated in the spillway entrance channel. The spillway capacity as determined by CE Screening criteria is inadequate. We estimate the dam can adequately pass 66% of the PMF.

We recommend that all trees be removed from the area of the embankment. This should be done soon. Eroded areas of the dam should be repaired and upstream riprap provided on the slope of the embankment at the right side of the spillway. This should be done soon. Cracked stairs should be repaired and vegetal growth removed. This should be done soon. The engineering properties of the foundation and earth embankment and concrete portions of the dam should be used to evaluate and confirm our assumptions concerning the stability of the dam and appurtenances under different stress conditions using present day analytical methods. This should be done soon. The deteriorated right sidewall of the spillway discharge channel and asphalt pavement of fountain discharge channel should be repaired. This should be done soon. The missing trash racks should be cleaned and installed in the gatehouse forebays. This should be done soon. Repair spalled and cracked concrete where necessary. This should be done in the near future. The condition of the water level gages below present lake level should be checked and if found to be rusted, replaced. This should be done in the future.

The spillway capacity as determined by CE Screening criteria is inadequate. The actual capacity of the spillway and SDF should be determined using more precise and sophisticated methods and procedures. The need for and type of mitigating measures should be determined. Around the clock surveillance during periods of unusually heavy precipitation should be provided, and a warning system established. This should be done in the near future.


Dennis J. Leary, P.E.



OVERVIEW
LAKE HOPATCONG DAM
1 DECEMBER 1978

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

| | |
|----------------------------|---------------------------|
| NAME OF DAM: | LAKE HOPATCONG DAM |
| ID NUMBER: | FED ID No. NJ00327 |
| STATE LOCATED: | NEW JERSEY |
| COUNTY LOCATED: | MORRIS |
| STREAM: | MUSCONETCONG RIVER |
| RIVER BASIN: | DELAWARE |
| DATE OF INSPECTION: | DECEMBER 1978 |



LANGAN ENGINEERING ASSOCIATES, INC.

Consulting Civil Engineers
990 CLIFTON AVENUE
CLIFTON, NEW JERSEY
201-472-9366

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LAKE HOPATCONG DAM FED ID No. NJ00327

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PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

SECTION I PROJECT INFORMATION

1.1 General

Authority to perform the Phase I Safety Inspection of Lake Hopatcong Dam was received from the State of New Jersey, Department of Environmental Protection, Division of Water Resources by letter dated 20 November 1978. This Authority was given pursuant to the National Dam Inspection Act, Public Law 92-367 and by agreement between the State and the US Army Engineers District, Philadelphia.

The purpose of the Phase I Investigation is to develop an assessment of the general conditions with respect to safety of Lake Hopatcong Dam and appurtenances based upon available data and visual inspection, and, determine any need for emergency measures and conclude if additional studies, investigations and analyses are necessary and warranted. The assessment is made using screening criteria established in Recommended Guidelines for Safety Inspection of Dams prepared by the Department of Army, Office of the Chief of Engineers. It is not the purpose of the inspection report to imply that a dam meeting or failing to meet the screening criteria, is per se, certainly adequate or inadequate.

1.2 Project Description

Lake Hopatcong Dam is a 54 year old, 17-ft high, 271-ft long reinforced concrete gravity type dam with left and right earth embankment sections. The central portion of the dam is a 100-ft long concrete overfall spillway. At the right side of the spillway is an earth embankment and at the left side is a gatehouse with an earth embankment at the extreme left. A concrete core wall is reported to be in the embankment sections of the dam. The gate works consist of four gates each 3-ft wide by 5-ft high and a 24-in-dia CI pipe that feeds a water fountain downstream of the dam. There is reported to be a 12-ft to 16-ft deep steel sheet pile cut-off below the dam that was driven into impervious material. The spillway is 13-ft high from the apron to crest and has a 22-ft base width and a 4-ft top width. The right embankment has an 8 to 10 ft wide crest, 2 Hor. to 1 Vert downstream slope, and a 4 to 5 Hor to 1 Vert upstream slope. The left embankment has an approx 200 ft wide crest and relatively flat upstream and downstream slopes.

The dam is located immediately north of Lakeside Blyd. in Netcong Borough, Morris County, New Jersey. It is at North latitude $40^{\circ} 55.1'$ and west longitude $74^{\circ} 39.9'$. A regional vicinity map is given in Fig 1 and essential features of the dam are given in Fig 2.

Lake Hopatcong Dam is classified as being "Large" on the basis of its maximum reservoir storage volume of 59,250 ac-ft, which is more than 50,000-acre feet. It is classified as "Small" on the basis of its total height of 17 feet, which is less than 40 feet. The overall size classification is the larger of these two determinations, and accordingly the dam is classified as "Large" in size.

In the National Inventory of Dams, Lake Hopatcong Dam has been classified as having "High Hazard Potential" on the basis that failure of the dam would cause excessive property damage to residences downstream, and could potentially cause more than a few deaths. Visual inspection of the downstream area shows that breach of the dam would cause damage to residences and be hazardous to people utilizing Lakeside Blvd. Accordingly, it is proposed not to change the Hazard Potential Classification.

The owner of the dam is the N.J. Div. of Forest and Parks, Labor and Industry Bldg. Room 806, P.O. Box 1420, Trenton, N.J. 08625. The purposes of the dam are flood control and recreation.

Very little essential information is available concerning the design and construction of the dam. The dam replaced and was built 25 ft downstream from an old dam that was part of the Morris Canal. It was designed by Mr. C.C. Vermeule, Consulting and Directing Engineer for the Morris Canal and Banking Company and construction was completed in 1925 by the Gotham Construction Corp. Minor repairs have been made to the dam in 1970 and 1975.

Normal operating procedures consist of maintaining lake level close to spillway elevation until the first of November after which the lake level is lowered 2.5 ft below spillway crest by 15 December. Every 5 years it is lowered 80 inches. This is to be done in 1980.

1.3 Pertinent Data

- | | | |
|----|--|---|
| a. | Drainage Area at dam site | 25.4 sq mi |
| | Lake area: | 3.87 sq mi (2474 Ac.) |
| b. | Discharge at Dam Site | |
| | Maximum known flood at dam site: | October 1903; peak flow reported to be 2331 cfs |
| | Ungated spillway capacity at maximum pool elevation: | 3073 cfs |

| | | |
|----|---|---|
| | Total discharge capacity at maximum pool elevation if gates are opened: | 4170 cfs |
| c. | Elevation (ft above MSL) | |
| | Top dam: | El. 927.7 |
| | Maximum pool-design surcharge: | El. 927.7 (assumed to be top of dam) |
| | Spillway crest: | El. 923.3 |
| | Streambed at centerline of dam: | El. 910.70 |
| | Maximum tailwater: | Approx. El. 911 at time of inspection |
| d. | Reservoir | |
| | Length of maximum pool: | Approx. 36,000 feet |
| e. | Storage (acre-feet) | |
| | Normal pool: (water surface equal to spillway crest) | Approx. 48,209 AF |
| | Top of dam: | Approx. 59,250 AF |
| f. | Reservoir Surface (acres) | |
| | Top dam: | 2550 Ac. |
| | Maximum pool: | 2550 Ac. |
| | Spillway crest: | 2474 Ac. |
| g. | Dam | |
| | Type: | Reinforced concrete gravity with earth embankment at both ends. |
| | Length: | 271 feet |
| | Height: | 17 feet |
| | Top width: | 8 ft to 10 ft (4 ft at spillway section) |
| | Side slopes: | Right side: U/S approx. 4 Hor : 1 Vert, D/S 2 Hor : 1 Vert Left side: U/S approx. 10H:1V, D/S approx. 5H:1 |

| | | |
|----|--------------------|---|
| | Zoning: | None observed |
| | Impervious core: | Concrete core wall reported in embankment section. |
| | Cutoff: | 12 ft to 16 ft deep sheet pile cutoff reported. |
| | Grout curtain: | None observed |
| h. | Spillway | |
| | Type: | Over-fall |
| | Length of weir: | 100 feet |
| | Crest elevation: | El. 923.3 |
| | U/S Channel: | Entrance channel from lake approx. 150 ft wide and 250 ft long. |
| | D/S Channel: | Paved with masonry sidewalls |
| i. | Regulating Outlets | Four 3 ft by 5 ft sluice gates and 24-in-dia gate valve in gatehouse. (Outlet discharge controlled by fountain outlet at downstream from dam) |

SECTION 2 ENGINEERING DATA

2.1 Introduction

There is essentially no information available concerning structural design of the dam. Borings are reported to have shown boulders overlying sandy clay to hardpan which rests immediately upon rock and is water tight. The steel sheet pile cut-off under the dam was driven into the hardpan. The dam and gatehouse are reported to have been so planned that the maximum weight on the foundation would not exceed 1 ton whereas the bearing capacity of the sandy clay was estimated at not less than 3 t/ft².

Design of the spillway is reported to be based upon the flood of October 1903 and also other floods occurring at Lake Hopatcong and elsewhere. Data concerning construction of the dam consists primarily of the specifications and progress reports. These data, although insufficient for a complete evaluation do indicate good judgement and practice was used with respect to the prevailing practice at the time the work was done.

Normal operating procedures consist of maintaining lake level close to spillway elevation until the first of November after which the lake level is lowered 2.5 ft below spillway crest by 15 December. Every 5 years it is lowered 80 inches. This is to be done in 1980.

2.2 Regional Geology

Lake Hopatcong Dam is located in the New Jersey Highlands physiographic province. The New Jersey Highlands extend across the State in a northeast/southwest direction from the border of New York to the Delaware River and includes the northwest portions of Hunterdon, Passaic, and Morris Counties and the southeastern parts of Warren and Sussex Counties. This province is part of the New England Physiographic Province and lies between the Appalachian Ridge and Valley Province to the northwest and the Piedmont Province to the southeast, See Fig 3.

The Highlands are characterized by rounded and flat-topped northeast/southwest ridges and mountains up to 1,400 ft high separated by narrow valleys. The orientation of the valleys are usually, but not always controlled by the underlying geologic structure.

Bedrock of the region is predominantly Precambrian gneisses, schists, and metasediments. Some sedimentary strata, typically sandstones, shales and conglomerate have been infolded and unfaulted into the valley bottoms.

The regional geologic structure reflects the very old age of bedrock. A number of regional faults cross the area in a northeast southwest direction, including the Ramapo Fault; the more than 30 mile long fault/scarp forms the eastern border of the province. Faults control many of the river valley orientations. The relatively uniform slope of the mountain elevations, from northwest to southeast, is a direct result of the faulting. The entire area is part of the now dissected Schooley Peneplain.

The Pleistocene Age Wisconsin glacier covered all of the dam site area.

The glacier stripped most of the existing overburden and weathered rock and uncovered the numerous hard bedrock knobs and ridges seen throughout the province. Most of the side-slopes in the area are covered with heavy boulder tills (ground moraine), whereas glacial outwash and recent alluvium cover the valleys.

SECTION 3 VISUAL INSPECTION

Lake Hopatcong Dam is 54 years old and in fair condition. There are some opened construction joints and minor concrete deterioration on the downstream side of the spillway otherwise the spillway section appears in adequate condition.

Concrete at the left intake structure wall has two approximately 1/8 inch wide cracks and the concrete has deteriorated at water level. Erosion has occurred below the crest of the dam on the upstream side at the junction of the right spillway sidewall and the embankment.

Small trees and brush cover the downstream slope of the right embankment.

The steps located on the downstream side of the right embankment have cracked and vegetation is growing through the steps. The steps located on the downstream side of the left embankment have also cracked but to a lesser degree.

The gatehouse concrete has several shrinkage cracks and two of the gratings have rusted. Four crank type operators for the sluice gates are located in the gatehouse. They are in satisfactory working order. A wheel operator for the 24-in gate valve which routes water to a fountain located downstream of the gatehouse is also in the gatehouse and in satisfactory condition. The right sidewall of the discharge channel has deteriorated. Sediment has occurred in the spillway entrance channel. The asphalt in the discharge channel for the fountain has deteriorated.

Our visual inspection check list is given in Appendix 1 and photographs are given in Appendix 2.

SECTION 4 OPERATION PROCEDURES

Normal operating procedures consist of maintaining lake level close to spillway elevation until the first of November after which the lake level is lowered 2.5 ft below spillway crest by 15 December. Every 5 years it is lowered 80 inches. This is to be done in 1980.

Except for specifically authorized changes to meet some particular situation, water discharge from the dam from November 1st to December 15th annually is limited. If the water level in the lake is 30 inches or more below the crest of the spillway, water discharge from the dam from November 1st to December 15th annually is limited to that automatically fed into the Musconetcong River by the fountain outlet below the dam. If the water level in the lake is less than 30 inches below the crest of the spillway on November 1st the gates are opened to discharge 18 cubic feet per second. This discharge from

the gates is maintained until December 15th unless or until the water level in the lake reaches 30 inches below the crest of the spillway, which is the maximum drawdown allowed without special authorization.

The dam appears to be maintained about every five years and the operating facilities are maintained about four times a year. There are no warning systems in effect.

It is our opinion the operational procedures are followed and the dam operating facilities are generally well maintained.

SECTION 5 HYDRAULIC/HYDROLOGIC

Available information indicates that the spillway and gates were designed based on the flood of October 1903. The peak flow for this storm is reported to be 2331 cfs.

The hydraulic/hydrologic evaluation is based on a Spillway Design Flood (SDF) equal to the full Probable Maximum Flood (PMF) in accordance with the evaluation guidelines for dams classified as high hazard and large in size. Hydrologic design data for this dam is not available. The PMF has been determined by developing a synthetic hydrograph based on the maximum probable precipitation of 22.4 inches (200 square mile - 24 hour). Hydrologic computations are presented in Appendix 4. The PMF determined for the subject watershed is 15,026 cfs.

The capacity of the spillway is 3073 cfs which is significantly less than SDF.

Flood routing for the PMF with the gates closed indicates the dam will overtop by 1.6 ft. We estimate the dam with gates closed can adequately pass 66% of the PMF. With the gates assumed to be opened after the start of the storm, the dam would overtop under the PMF by 1.12 ft and would adequately pass 77% of the PMF.

The downstream potential damage center (a reasonably well traveled road and nearby residential buildings), is located a few hundred feet from the dam. Based on our visual inspection of the immediately downstream topography and knowledge of the dam it is our opinion that dam failure resulting from overtopping would increase the hazard to loss of life downstream from the dam from that which would exist just before overtopping failure.

Our calculations indicate the lake level could be lowered 7 ft in approximately 10 days and 11 ft in about 29 days.

SECTION 6 STRUCTURAL STABILITY

Based on our visual observations and review of available records it is our opinion, Lake Hopatcong Dam and appurtenances can be assumed to be stable. However, because there is very little available information concerning the embankment and foundation materials it is not possible to ascertain analytically whether or not the dam and appurtenances are within conventional safety margins. Post construction changes have consisted primarily of minor maintenance. No major stability problems have been reported during the life of the dam.

Lake Hopatcong Dam is located in Seismic Zone I of the Seismic Zone Map of Contiguous States. The degree of stability of the dam and appurtenances is assumed to be within conventional safety margins and to present no hazard from earthquakes. If, however, the Seismic Zone rating is increased in the future, or data becomes available to indicate it may be increased, further study with respect to seismic stability may be necessary.

SECTION 7 ASSESSMENT, RECOMMENDATIONS/REMEDIAL MEASURES

7.1 Assessment

Lake Hopatcong Dam is 54 years old and in fair overall condition. There are trees and brush on the downstream slope of the embankment at the right of the spillway. The concrete on the spillway and gatehouse has cracked or spalled at a few locations. The trash racks have rusted and are not in place at two of the forebays. Erosion has occurred upstream of the right embankment and at the junction of the embankment and spillway right sidewall. The stairs at the downstream side of the right embankment and at the left side of the gatehouse have cracked and there is vegetal growth in the cracks. The right sidewall of the spillway discharge channel and the fountain discharge channel asphalt have deteriorated. Sediment has accumulated in the spillway entrance channel. The spillway capacity as determined by CE Screening criteria is inadequate. We estimate the dam can adequately pass 66% of the PMF.

We recommend the following remedial measures:

- 1. Remove all trees from the area of the embankment. This should be done soon.**
- 2. Repair eroded areas of the dam and provide upstream riprap on the slope of the embankment at the right side of the spillway. This should be done soon.**
- 3. Repair cracked stairs and remove vegetal growth. This should be done soon.**
- 4. Investigate the engineering properties of the foundation and earth embankment and concrete portions of the dam by means of borings and tests. This information should be used to evaluate the stability of the dam and appurtenances under different stress conditions using present day analytical methods. This should be done soon.**
- 5. Repair deteriorated right sidewall of spillway discharge channel and asphalt pavement of fountain discharge channel. This should be done soon.**
- 6. Clean and install trash racks in gatehouse forebays. This should be done soon.**
- 7. Repair spalled and cracked concrete where necessary. This should be done in the near future.**
- 8. Check condition of water level gages below present lake level and if found to be rusted, replace the gages. This should be done in the future.**
- 9. The spillway capacity as determined by CE Screening criteria is inadequate. The actual capacity of the spillway and SDF should be determined using more precise and sophisticated methods and procedures. The need for and type of mitigating measures should be determined. Around the clock surveillance during periods of unusually heavy precipitation should be provided, and a warning system established. This should be done in the near future.**



1 in \approx 5.2 mi

REGIONAL VICINITY MAP
LAKE HOPATCONG DAM

Fig. 1

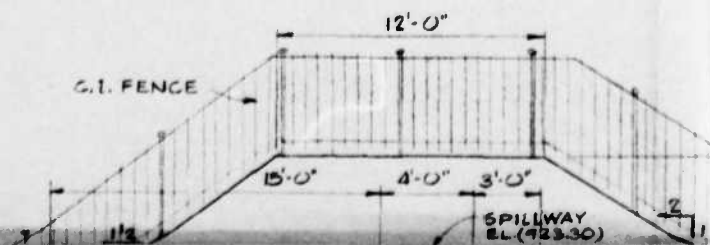
1



STEEL SHEET
PILING

TYPICAL SECTION
THRU CONC. CORE WAL

SCALE: 1" = 4'



2

• (924.43)

(922 80)

(३२१. ३५)

8721.42

(721.03)

1720 83)

• (722.02)

Am 12/12

STONE WALL

 $(720, \pi_0)$

(722.79)

LAKE HOP
(EL. 92)

STEEL SHEET
PILING

SECTION
CORE WALL

1"-4'

TOP OF WINGWALL
EL(927.70)

PILLWAY
L (92330)

CONC. CURB WALL

TREES AND BRUSH

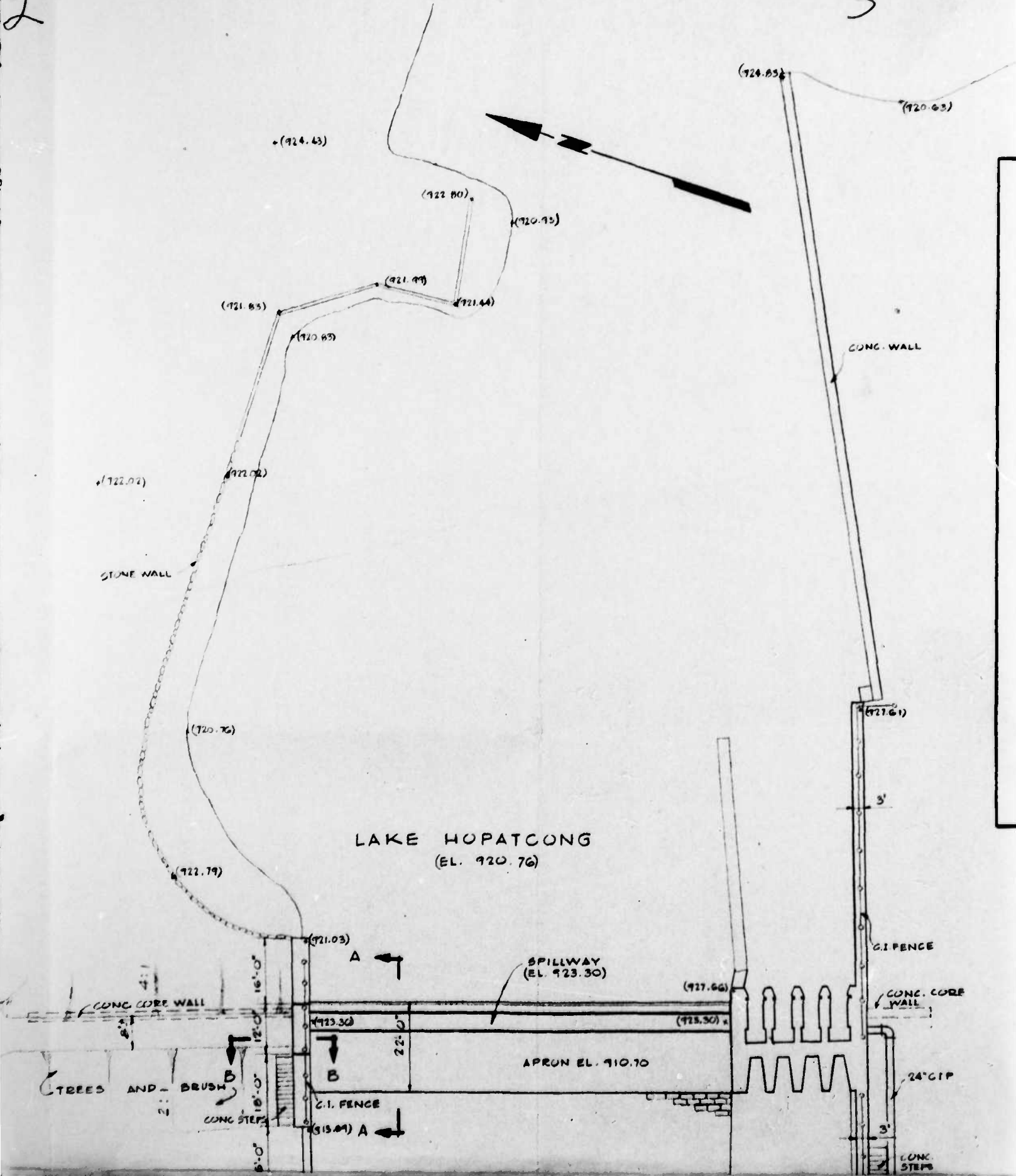
LONG STEPS

C.I. FENCE

4515-21 A

2

3



3

4

(724.85)
(720.63)

(720.63)

CONC. WALL

(727.61)

3'

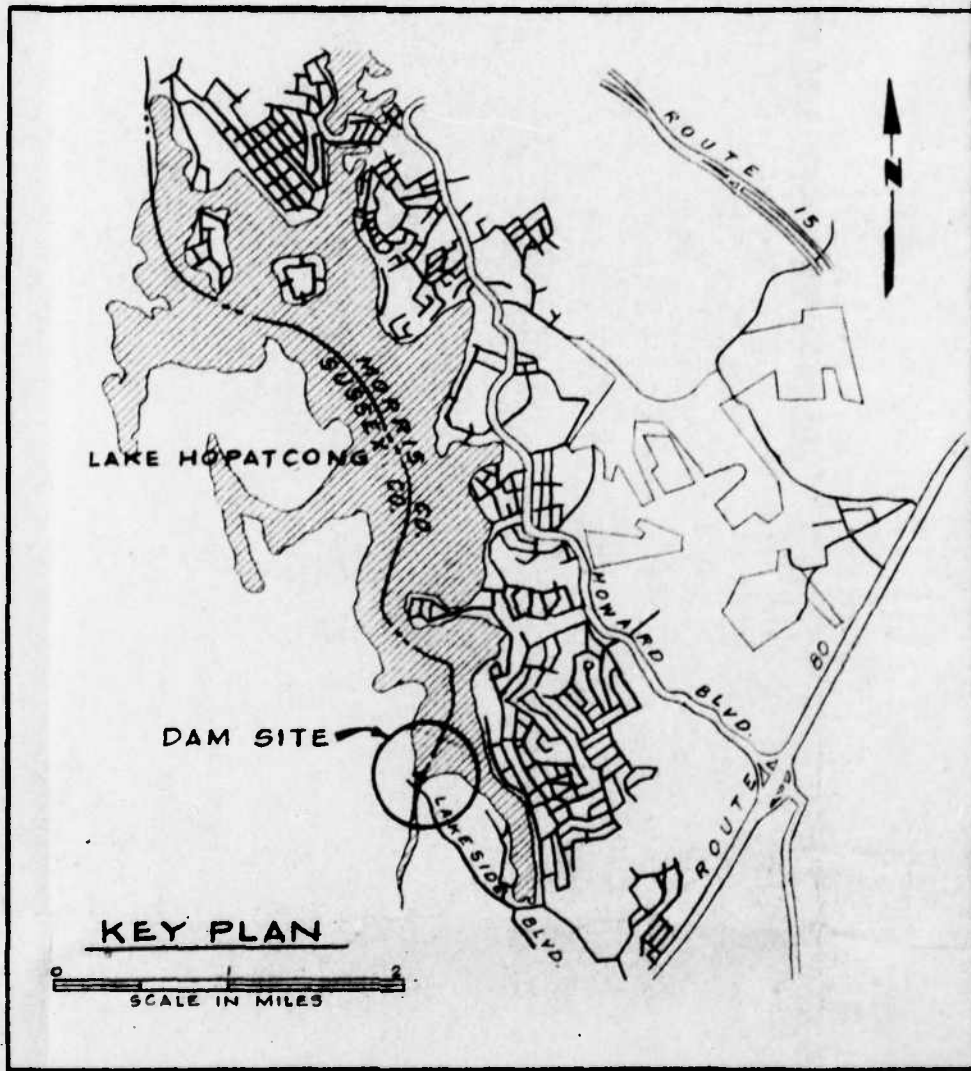
G.I. FENCE

CONC. CORE WALL

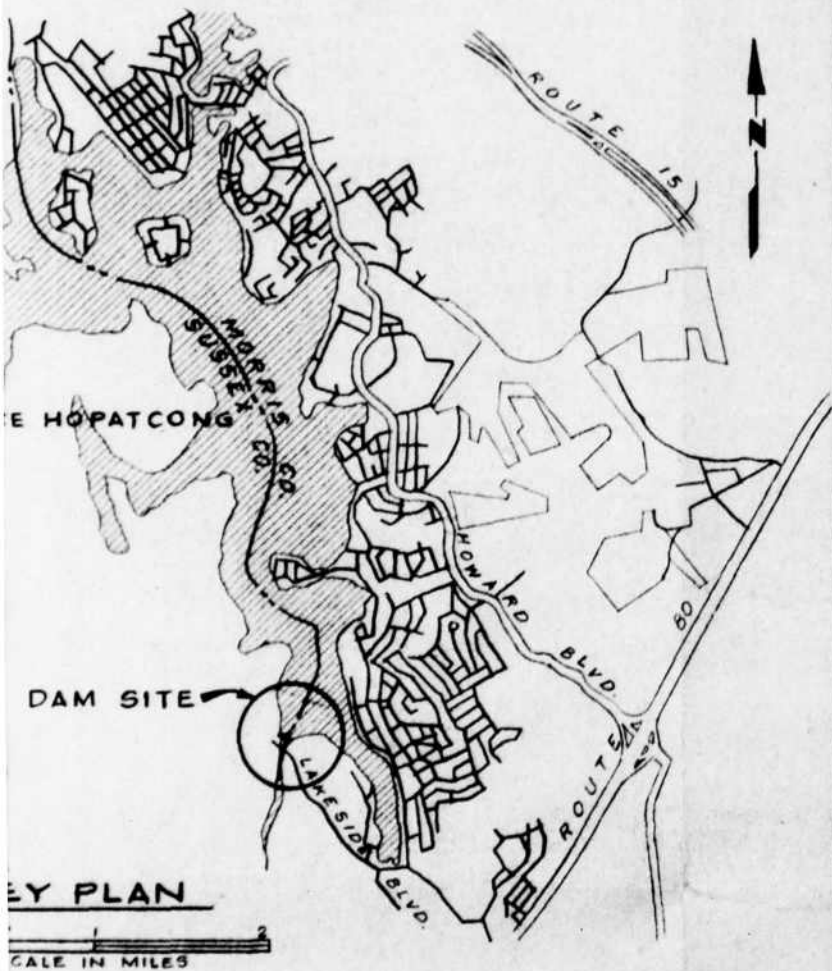
24" CIP

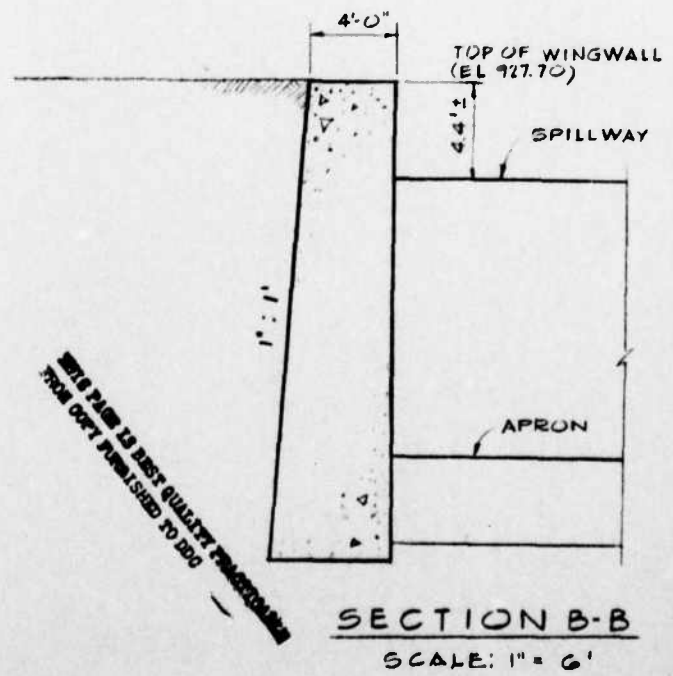
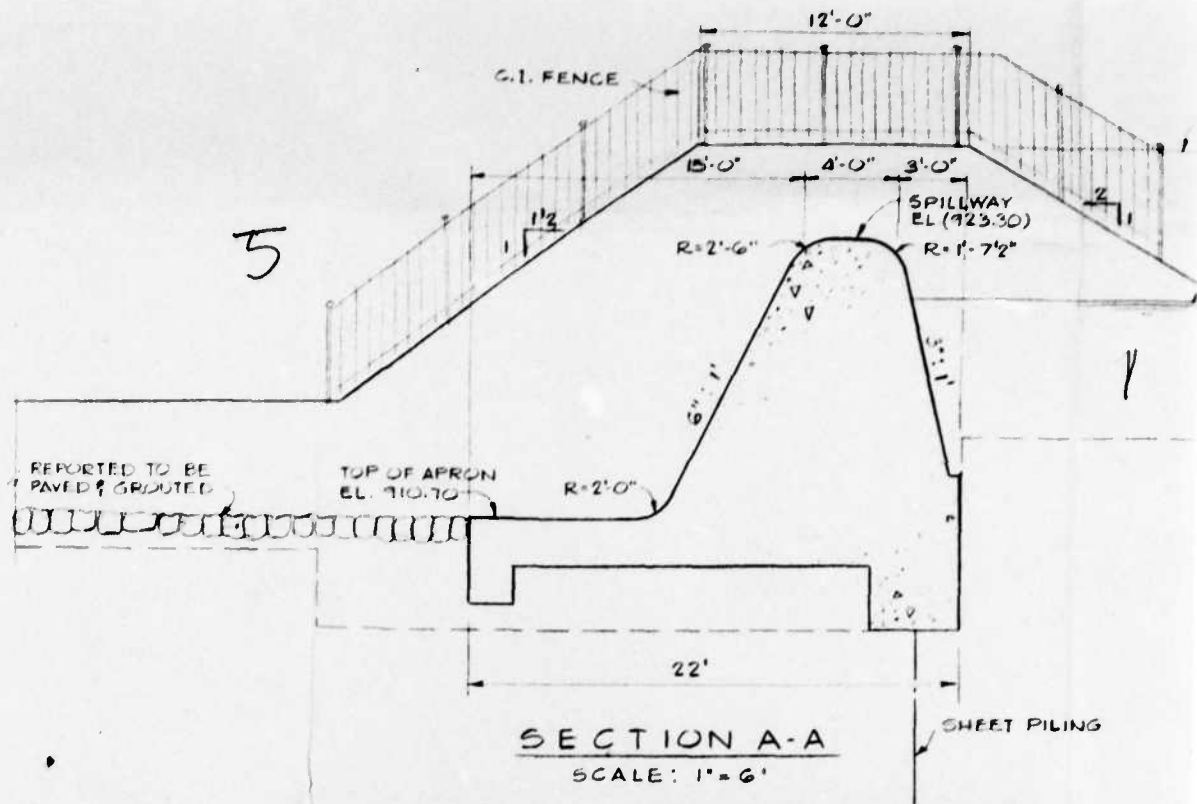
3'

CONC. STEPS



4



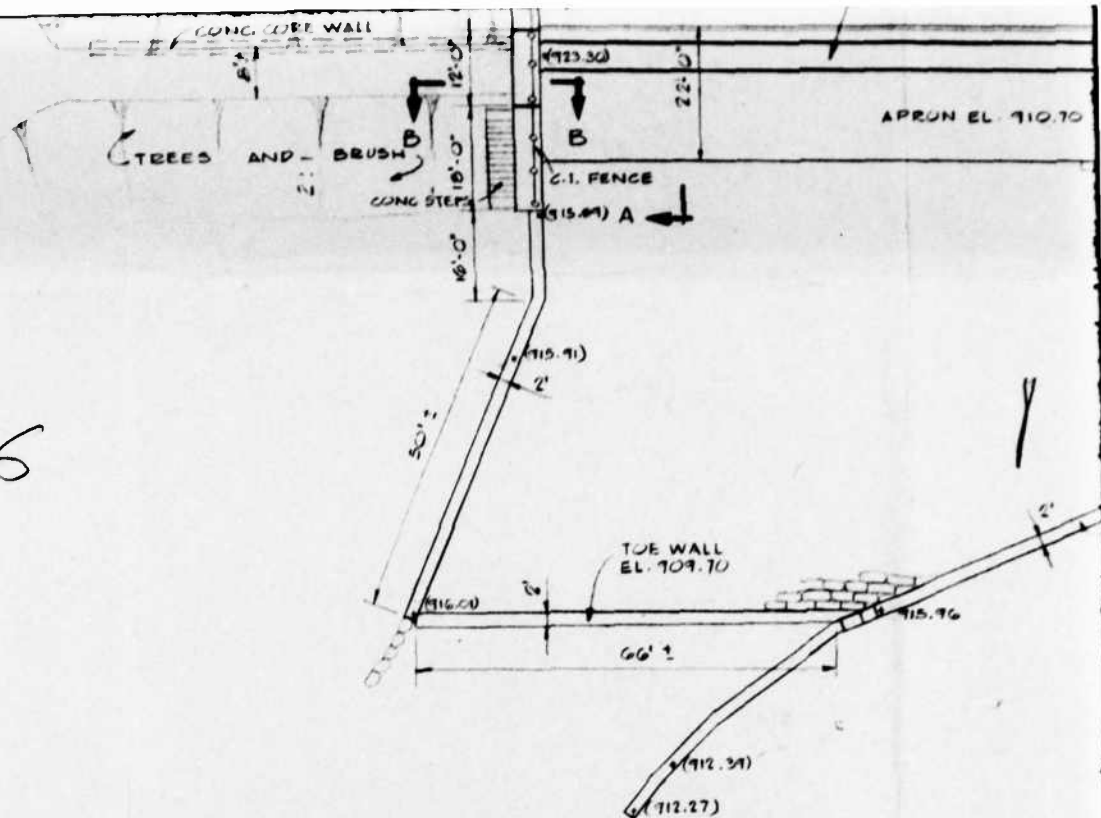


TOP OF WINGWALL
EL (927.70)

WATER (EL. 920.76)

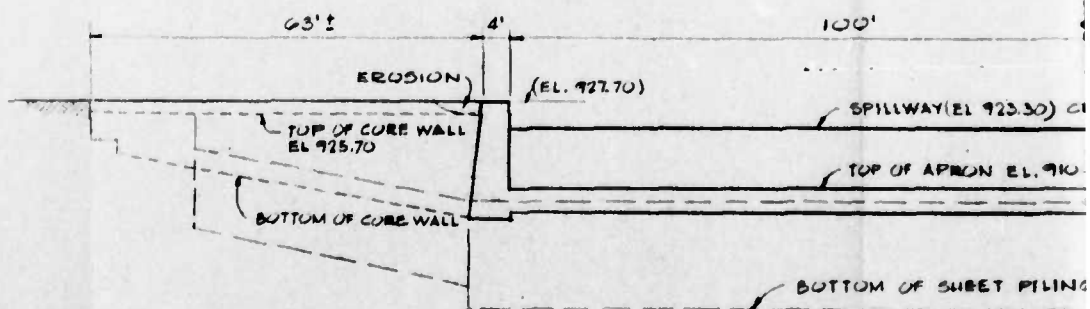
EL 914.5

6



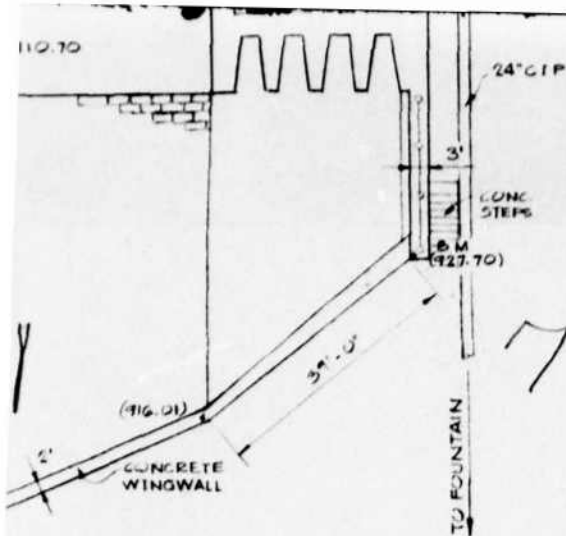
PLAN

SCALE: 1" = 20'

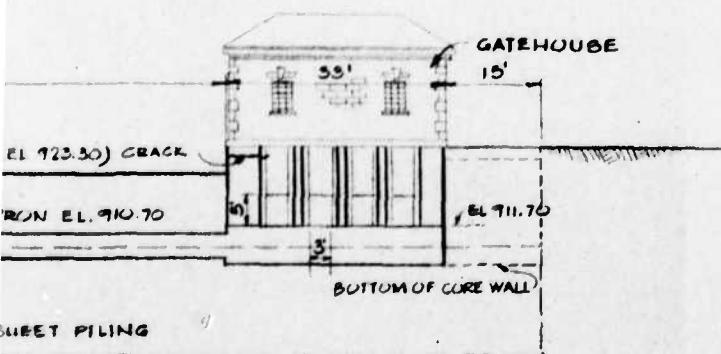


ELEVATION

SCALE: 1" = 20'



8



NOTE:

THE ELEVATIONS SHOWN WERE OBTAINED USING A SURVEYOR'S TRANSIT AND LEVEL, AND DRAWINGS OF THE MORRIS CANAL & BANKING CO., DOVER, N.J. OFFICE, AUG 16, 1924. THE BENCHMARK ELEVATION OF 927.70 ON THE WINGWALL SOUTH OF THE GATEHOUSE WAS USED AS SHOWN ON SAID DWGS. ELEVATIONS IN PARENTHESES FROM LANGAN ENG. ASSOC. INC. FIELD SURVEY. ELEVATIONS ARE APPROXIMATE. INFORMATION SHOWN BELOW GROUND SURFACE AND WATER LEVEL ARE INFERRED ON THE BASIS OF THE ABOVE MENTIONED DRAWINGS.

FOR OR OTHERWISE FROM ANY SOURCE OR FOR ANY PURPOSE

| DATE | DESCRIPTION | NO. |
|-----------|-------------|-----|
| REVISIONS | | |



PROJECT

PHASE I INSPECTION & EVALUATION of NEW JERSEY DAMS

DRAWING TITLE

LAKE HOPATCONG DAM

JANUARY 1979
FED. I.D. NO. NJ00327

| | |
|---------|-------------|
| JOB NO. | J-785B |
| DATE | 24 FEB 1979 |
| SCALE | AS NOTED |
| DRN. BY | J. R. |
| CHKD BY | |

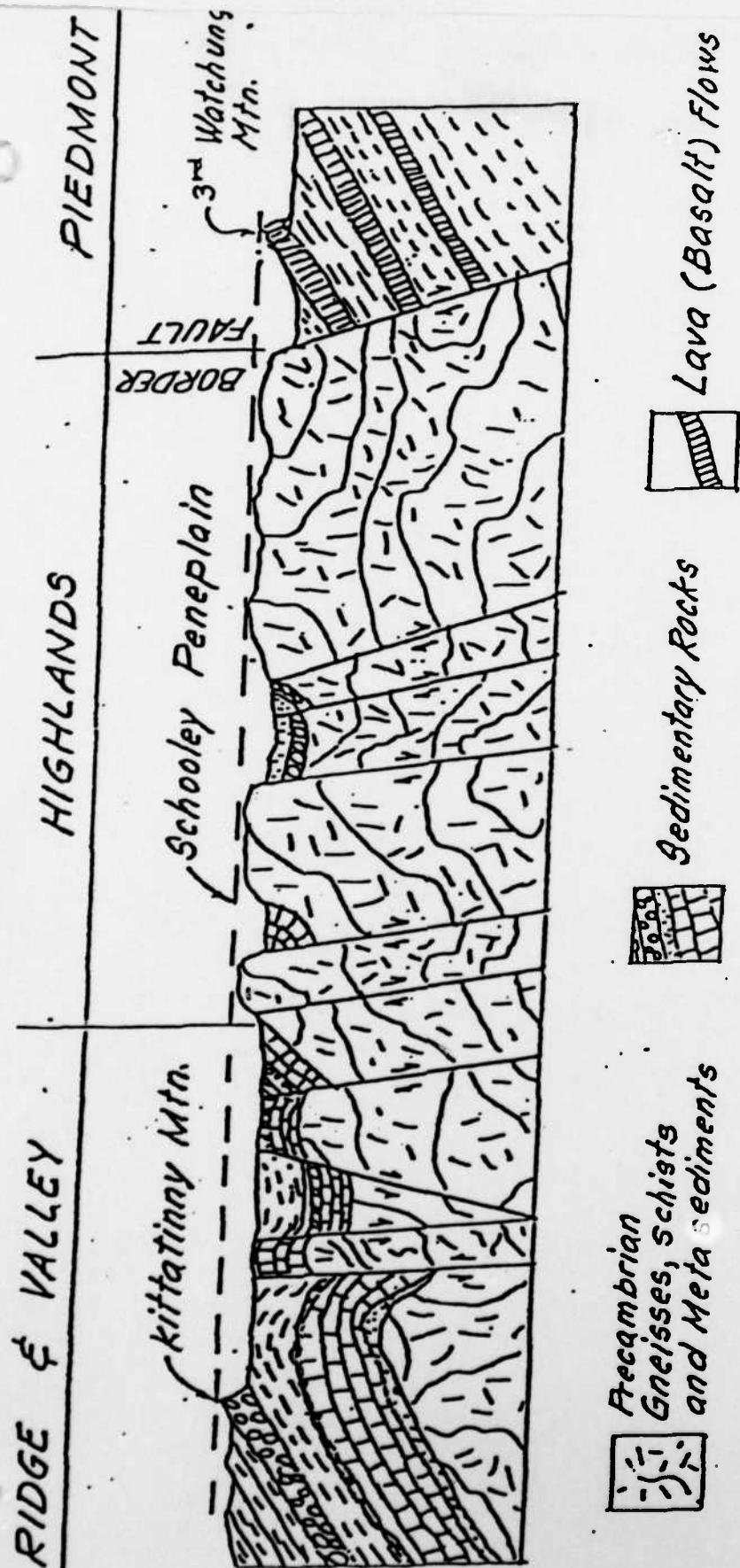
DRAWING NO.

FIG 2

THIS PAGE IS BEST QUALY PRACTICAL

NOTE:

THE ELEVATIONS SHOWN WERE OBTAINED USING A SURVEYOR'S TRANSIT AND LEVEL, AND DRAWINGS OF THE MORRIS CANAL & BANKING, DOVER, N.J. OFFICE, AUG 16, 1924. THE BENCHMARK ELEVATION 927.70 ON THE WINGWALL SOUTH OF THE GATEHOUSE WAS USED SHOWN ON SAID DWGS. ELEVATIONS IN PARENTHESES FROM INGAN ENG. ASSOC. INC. FIELD SURVEY. ELEVATIONS ARE APPROXIMATE. FORMATION SHOWN BELOW GROUND SURFACE AND WATER LEVEL LE INFERRED ON THE BASIS OF THE ABOVE MENTIONED DRAWINGS.



*Schematic Cross-section,
New Jersey Highlands
Physiographic Province
(After Wolfe, 1977)*

APPENDIX I

CHECK LIST

VISUAL INSPECTION

LAKE HOPATCONG LAKE DAM

CHECK LIST
VISUAL INSPECTION
Phase I

NAME DAM Lake Hopatcong Dam COUNTY Morris STATE New Jersey COORDINATORS N.J. DEP

DATE(s) INSPECTION See Below WEATHER Overcast TEMPERATURE 48° F

POOL ELEVATION AT TIME OF INSPECTION 920.8* M.S.L. TAILWATER AT TIME OF INSPECTION 911+* M.S.L.

* BM of 927.7 (Ref. Note Fig 2)

INSPECTION PERSONNEL:

| | | | |
|--------------------|-----------------|---------------------|-----------------|
| <u>D. Leary</u> | <u>12/7/78</u> | <u>P. Yu</u> | <u>12/18/78</u> |
| <u>J. Richards</u> | <u>12/7/78</u> | <u>J. Gurkovich</u> | <u>12/18/78</u> |
| <u>J. Rizzo</u> | <u>12/18/78</u> | | |

James Richards RECORDER

EMBANKMENT

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|--|---|---|
| SURFACE CRACKS | None observed | |
| UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE | None observed | |
| SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES | Erosion at right spillway sidewall/ embankment abutment junction, upstream slope. | Eroded area should be suitably filled. |
| VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST | Appears satisfactory | |
| RIPRAP FAILURES | Upstream riprap deteriorated or misplaced. | Replace or provide upstream riprap to right embankment. |

EMBANKMENT

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|---|--|
| OTHER | Trees on downstream slope and toe of embankment. | Trees should be removed |
| JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM | Erosion at spillway sidewall embankment abutment. | Eroded area should be suitably filled. |
| ANY NOTICEABLE SEEPAGE | None observed | |
| STAFF GAGE AND RECORDER | Lake level gage at gate house. | Check condition of gage below water level, replace if necessary. |
| DRAINS | None observed | |

UNGATED SPILLWAY

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|-----------------------|---|---|
| CONCRETE WEIR | 1/8 inch wide crack across top and down upstream face. | Crack in spillway should be repaired. |
| APPROACH CHANNEL | Pieces of wood and debris in channel. | Wood and debris should be removed. |
| DISCHARGE CHANNEL | Dead branch, cans and logs in channel. | Debris should be removed. |
| BRIDGE AND PIERS | Concrete spalled and steel fence bottom rusted out on right wall of spillway. | Spalled concrete area and steel fence should be repaired. |
| | | |

OUTLET WORKS

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|-------------------------------|--|--------------------------------------|
| CONCRETE SILL | Not observable. | |
| APPROACH CHANNEL | Wood, paper and cans in channel. | Debris should be removed. |
| DISCHARGE CHANNEL | Appears satisfactory | |
| BRIDGE AND PIERS | Pier located second from left has concrete spalled on top 3 inches. | Spalled concrete should be repaired. |
| GATES AND OPERATION EQUIPMENT | 4 crank operator stems, Coffin Valve Co., Boston, FE 70J located in gatehouse. One wheel operator for water fountain. Appears satisfactory. Trash screens dirty. | |

OUTLET WORKS

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|--------------------------------------|---|----------------------------|
| SURFACE CRACKS CONCRETE SURFACES | Concrete spalled at water level on left abutment. On sill of gatehouse, pulley support system base plates rusting and uplifted on gatehouse sill, | |
| STRUCTURAL CRACKING | Cracks on right abutment steps. | Repair cracks. |
| VERTICAL AND HORIZONTAL ALIGNMENT | Appears satisfactory | |
| MONOLITH JOINTS | Appears satisfactory | |
| CONSTRUCTION JOINTS | Appears satisfactory | |

OUTLET WORKS

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|--|--|---------------------------------|
| | | |
| STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS | Erosion at right abutment 2 ft by 10 ft by 1 ft deep. | Eroded area should be repaired. |
| DRAINS | None observed | |
| WATER PASSAGES | Wood, brush, and leaves in several locations. | Remove debris. |
| FOUNDATION | Not observable | |

DOWNSTREAM CHANNEL

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|---|--|----------------------------|
| CONDITION (OBSTRUCTIONS, DEBRIS, ETC.) | Cans, dead branches, 55 gallon drums & an old shopping basket in channel. Right channel sidewall deteriorated. | |
| SLOPES | Debris on slope. | Debris should be removed. |
| APPROXIMATE NO. OF HOMES AND POPULATION | More than 50 homes, Lakeside Blvd. and L & W Railroad downstream, ref. USGS Topo Map. Population of Hopatcong Heights 9,052, 1970 Census. | |
| | | |

RESERVOIR

| VISUAL EXAMINATION OF | OBSERVATIONS | REMARK OR RECOMMENDATIONS |
|-----------------------|------------------------------------|----------------------------|
| SLOPES | Appears satisfactory | |
| SEDIMENTATION | Sedimentation in entrance channel. | Channel should be cleaned. |
| | | |
| | | |
| | | |

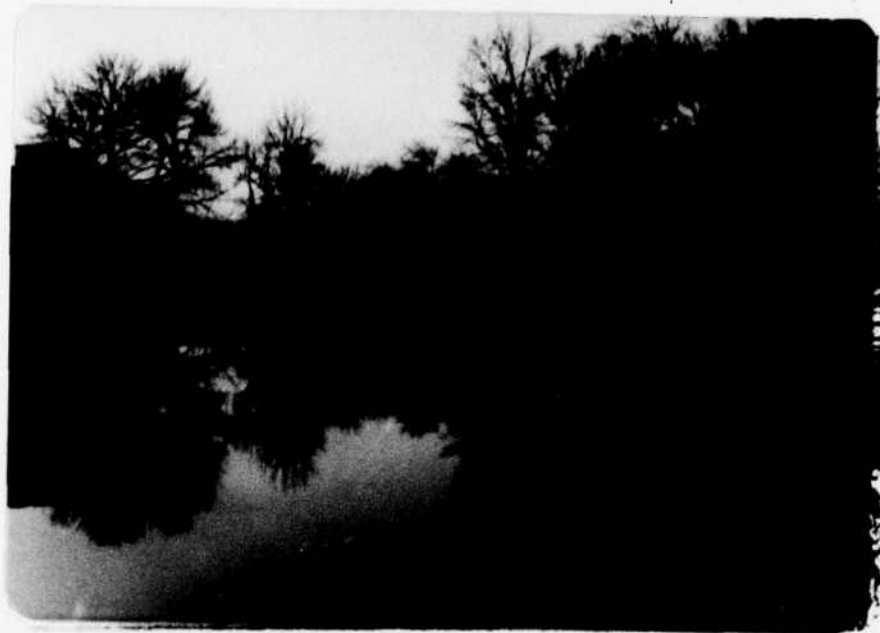
INSTRUMENTATION

| VISUAL EXAMINATION | OBSERVATIONS | REMARKS OR RECOMMENDATIONS |
|-----------------------|---|----------------------------|
| MONUMENTATION/SURVEYS | Survey marker on gatehouse sill. | |
| OBSERVATION WELLS | Well in gatehouse appears satisfactory. | |
| WEIRS | Concrete weir located under highway appears satisfactory. | |
| PIEZOMETERS | None observed | |
| OTHER | USGS & N.J. have measuring station. | |

APPENDIX 2

PHOTOGRAPHS

LAKE HOPATCONG LAKE DAM



Spillway. Looking Downstream.

7 December 1978



Lake Hopatcong. Looking upstream.

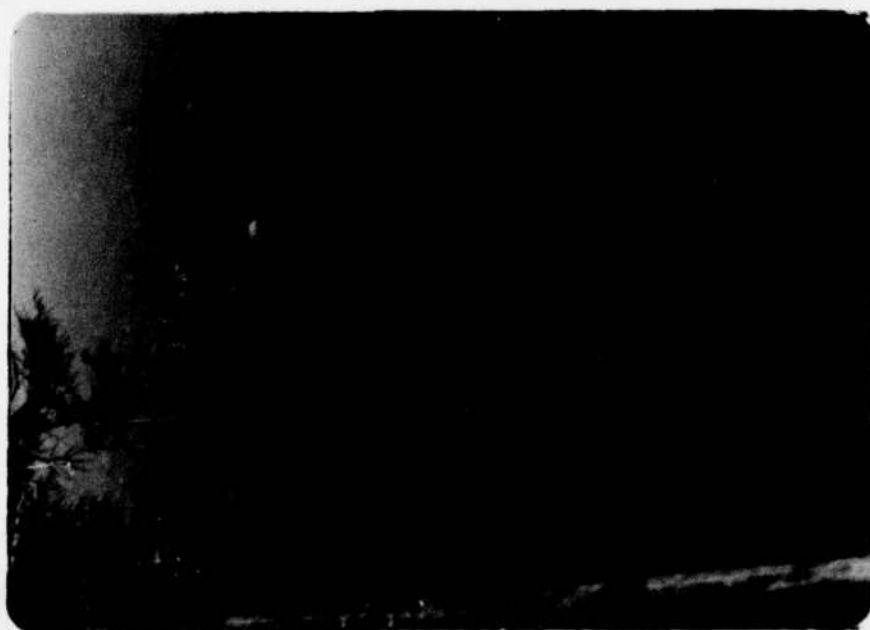
7 December 1978

LAKE HOPATCONG DAM



Embankment at right side of spillway.
Note absence of riprap.

7 December 1978



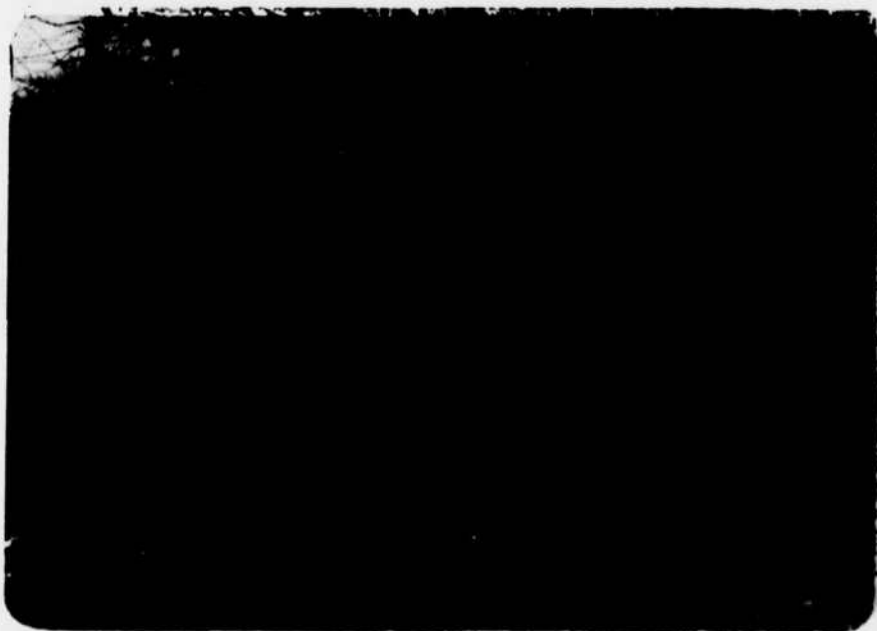
Sediment in spillway entrance channel.

7 December 1978

LAKE HOPATCONG DAM



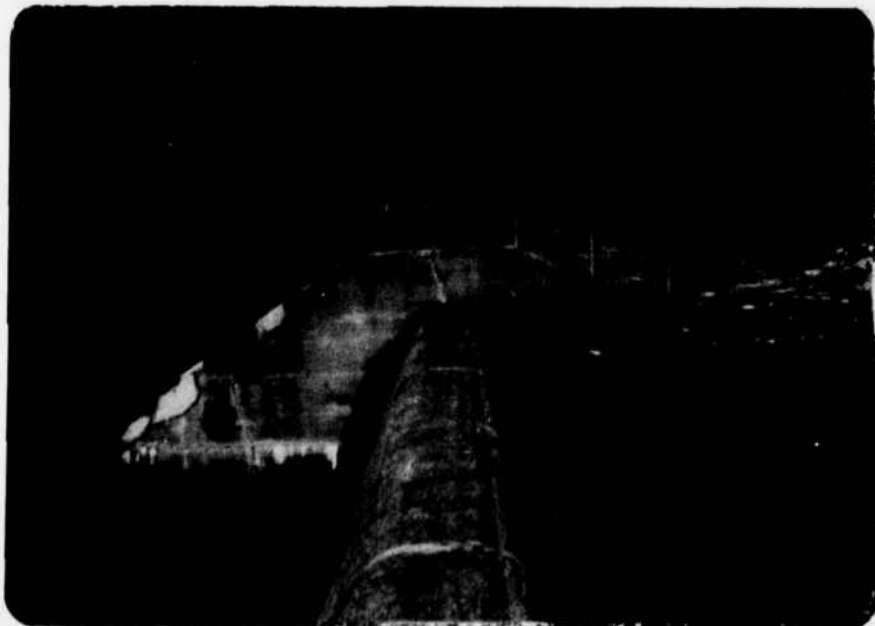
Trees on downstream slope of embankment 7 December 1978
at right side of spillway.



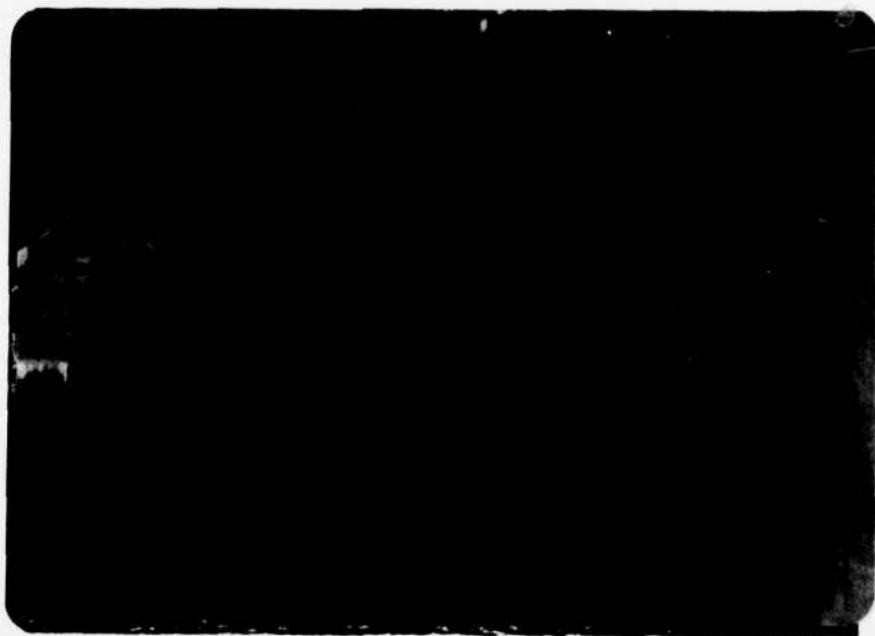
Upstream erosion of embankment. 7 December 1978



Erosion of right side of spillway side wall. 7 December 1978

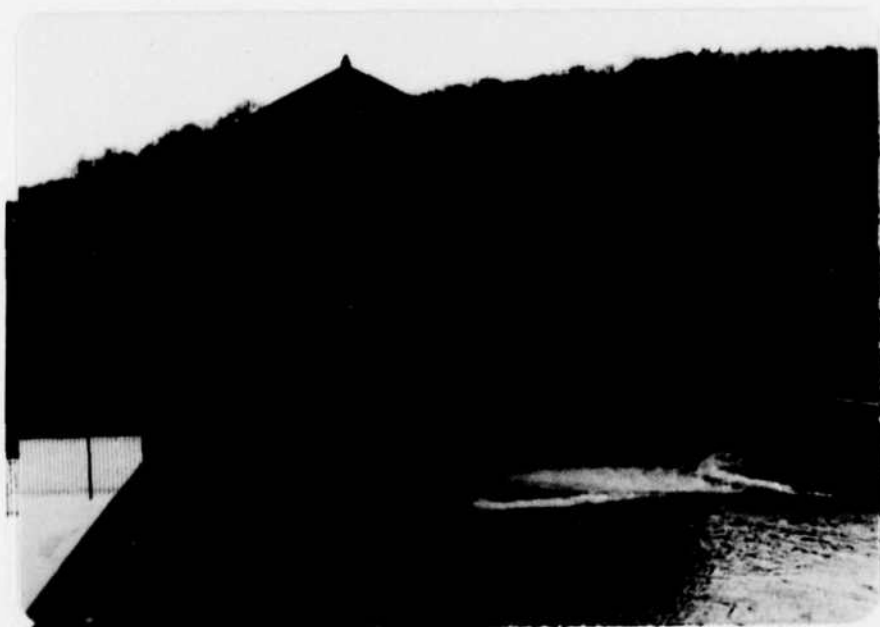


Crest of spillway. Note repaired cracks in spillway sidewall. 7 December 1978



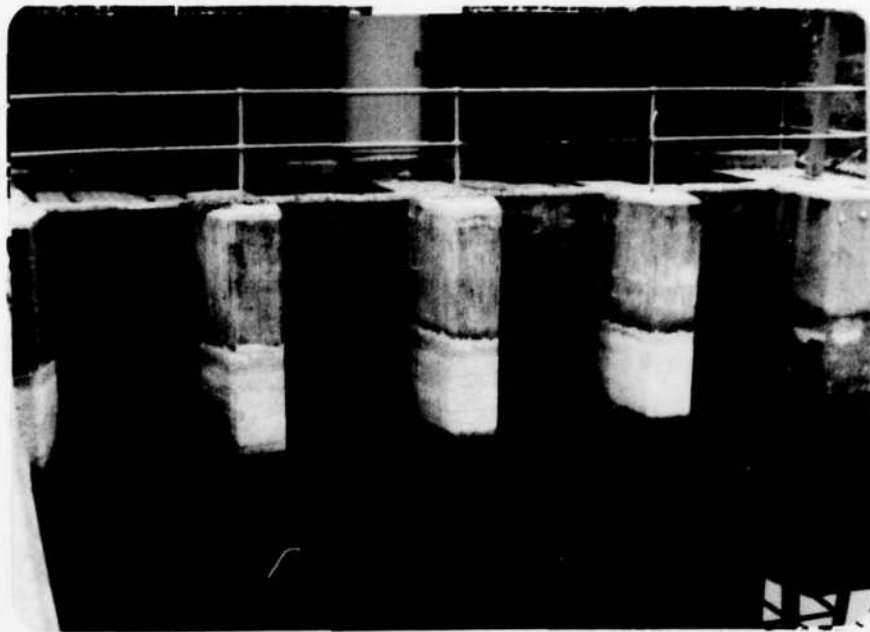
Spillway looking upstream.

7 December 1978



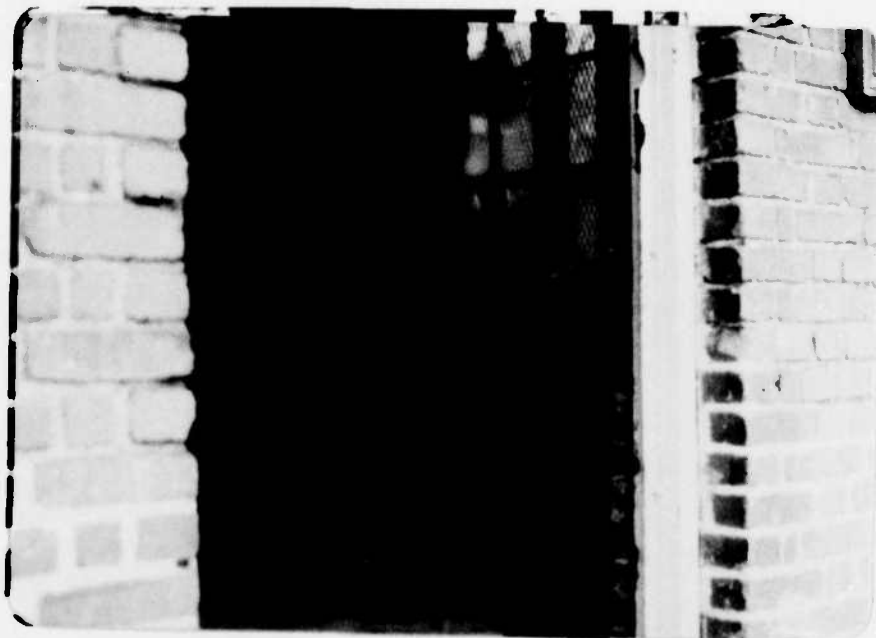
Gate house at left side of spillway.

7 December 1978



Gatehouse intake tunnels. Note trash racks not in place.

7 December 1978



Gate operators inside gatehouse.

7 December 1978

LAKE HOPATCONG DAM



Deterioration of discharge channel
right sidewall.

7 December 1978



Downstream constriction in discharge
channel.

7 December 1978



Deteriorated asphalt of discharge
channel for fountain.

7 December 1978



Discharge culvert under Lakeside Blvd.

7 December 1978

LAKE HOPATCONG DAM



Discharge channel and walkway under
Lakeside Blvd.

7 December 1978



Discharge channel below Lakeside Blvd.

7 December 1978

LAKE HOPATCONG DAM



Water level gage at gatehouse.

7 December 1978



Discharge from gatehouse during inspection.

7 December 1978

LAKE HOPATCONG DAM

APPENDIX 3

HYDROLOGIC COMPUTATIONS

LAKE HOPATCONG LAKE DAM

HYDROLOGICAL COMPUTATIONS LAKE HOPATCONG DAM

- A. Location : Morris - Sussex County
- B. Drainage Basin : 25.4 sq. mi.
Area of Lake : 2474 acres (3.87 sq. mi.)
- C. Classification :
Size - Large
Hazard - high

D. Spillway Design Flood (SDF) :

From available data, the gates and spillway are known to have been designed on the basis of the flood of Oct. 1903. In accordance with the evaluation guidelines, this flood is inadequate and PMF should be used.

E. PMP

1. Dam located in Zone 6

PMP = 22.4 inches

2. PMF must be adjusted for basin size

| Duration - hr. | % Factor (for sq. mi.) | Reduction Factor* |
|----------------|------------------------|-------------------|
| 0-6 | 104 | 0.82 |
| 0-12 | 113 | |
| 0-24 | 123 | |
| 0-48 | 135 | |
| | | * P.48 D.S.D. |

BY LogDATE 1-29-79Lake Hopatcong DamJOB NO. I-783BCKD GEDDATE 3-29-79SHEET NO. 1 OF 12

F. Unit Hydrograph :

Corp of Engineers has indicated that Snyder Method be used with the following coefficients

$$C_t = 3.70, C_p = 0.58$$

Snyder lag time :

$$t_p = C_t (L L_{ca})^{0.3}$$

from drainage area

$$L \doteq 55000 \text{ ft} \doteq 10.42 \text{ miles}$$

$$L_{ca} \doteq 25000 \text{ ft} \doteq 4.73 \text{ miles}$$

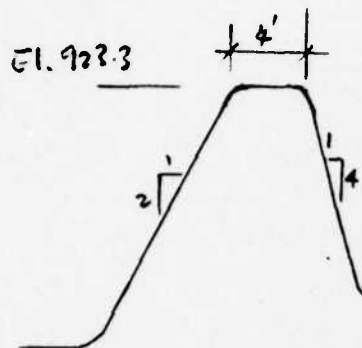
$$\therefore t_p = 3.7 (10.42 \times 4.73)^{0.3} \doteq 12 \text{ hrs.}$$

\therefore use $t_p = 12 \text{ hrs}$ and $C_p = 0.58$.

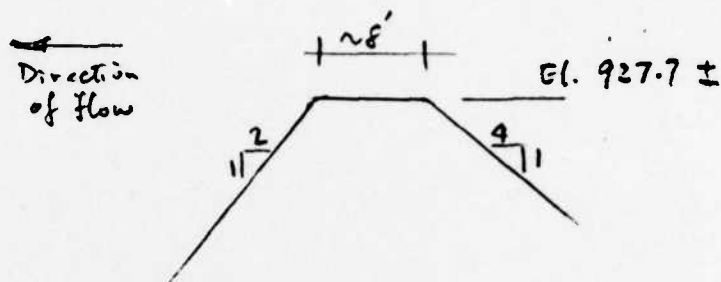


SPILLWAY CAPACITY

Spillway Section



Right Embankment Section



Discharge structures: 100 ft. wide spillway and 4 sluice gates 3' x 5'. There is a 24-in. dia pipe feeding to the fountain on downstream of the dam. From available data and records, the maximum discharge from the fountain when the lake is near the top of spillway is in the neighborhood of 15 cfs which is insignificant when compared to the discharge of the spillway and the sluiceway. \therefore its discharge is not considered in the analysis.

The spillway section resembles a trapezoidal section with rounded corners. Due to its rounded corners it also resembles slightly the ogee section with curves of small radii. From available data, the gates and spillway are known to have been designed on the basis of the flood of Oct. 1903. With this flood, the spillway was estimated to have a discharge of 914 cfs with 1.96 feet head.

$$\therefore C = \frac{Q}{LH^{3/2}} = \frac{914}{100 \cdot 1.96^{3/2}} = 3.33$$

Use $C = 3.33$ for the spillway.

The sill of the gates is 12 feet below normal lake surface (available information), but owing to back-water a working head of 9 feet was used in the design. The estimated total discharge from the 4 gates is 900 cfs

$$Q = CA\sqrt{2gh}, \quad C = \frac{Q}{A\sqrt{2gh}} = \frac{900}{60 \times 8.02\sqrt{9}} = 0.623$$

\therefore use $C = 0.623$ for orifice equation for the gates for draw down analysis. This is not included in developing the spillway rating curve.

The top of the right embankment is at approximately El. 927.7 (same as top of wing wall). Its typical section is similar to a trapezoidal section with both face inclined.

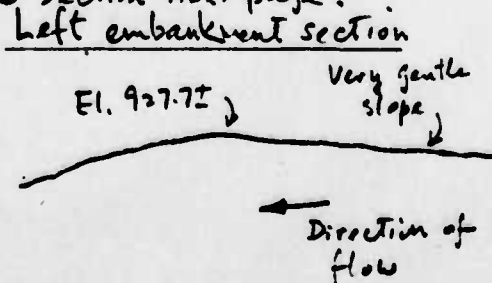
Use $C = 3.0$ for the weir equation for the embankment.

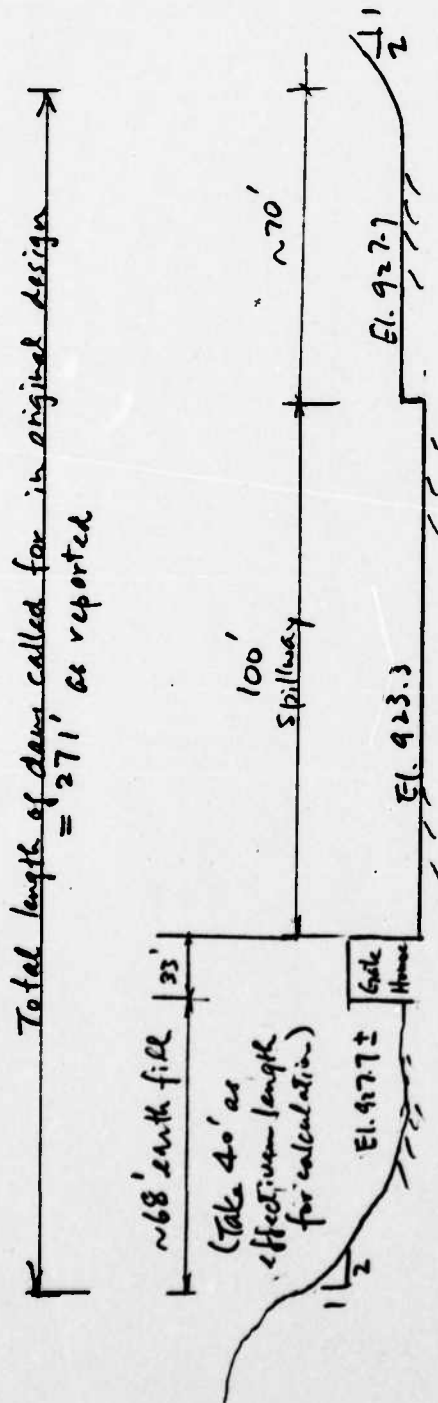
4' wide wing wall has similar section, use same C value.

Use an effective length of 70 feet for the right (north) embankment. This includes the width of the wing wall.

The portion to the left of the gate house is at El. 927.7 \pm . See schematic section next page.

Use $C = 2.7$
with an effective length
of 40 feet.





Schematic Longitudinal Profile of Dam
(Direction: looking downstream)

BY Phy
CKD GD

DATE 1-30-79
3-16-79
DATE 3-29-79

Lake Hopewell Dam

JOB NO. J-783B
SHEET NO. 5 OF 12

| Elev. (ft) | Spillway | | Right (North) Embankment | | Left (South) Embankment | | Sluice Gates | | Total (cfs) [Entire closed] $Q_E + Q_{RE} + Q_{LE}$ |
|---------------|----------|-------------|-----------------------------|-------------|----------------------------|----------------|--------------|-------------|---|
| | H (ft) | Q_S (cfs) | H (ft) | Q_E (cfs) | H (ft) | Q_{LE} (cfs) | H (ft) | Q_G (cfs) | |
| 923.3 | 0 | | | | | | | | 0 |
| 924.3 | 1 | 333 | | | | | 10 | 948 | 333 |
| 925.3 | 2 | 942 | | | | | 11 | 994 | 942 |
| 926.3 | 3 | 1730 | | | | | 12 | 1038 | 1730 |
| 927.7 | 4.4 | 3073 | 0 | | | | 13.4 | 1097 | 3073 |
| 928.7 | 5.4 | 4179 | 1 | 210 | | 108 | 14.4 | 1138 | 4497 |
| 929.7 | 6.4 | 5392 | 2 | 594 | | 305 | 15.4 | 1176 | 6291 |
| 930.7 | 7.4 | 6703 | 3 | 1091 | | 561 | 16.4 | 1214 | 8355 |
| 931.7 | 8.4 | 8107 | 4 | 1680 | | 864 | 17.4 | 1251 | 10651 |

* Sluice gates are assumed to be closed. ∴ their discharges are not included.

$$Q_S = 333 \text{ ft}^3/\text{s}$$

$$Q_{RE} = 210 \text{ ft}^3/\text{s}$$

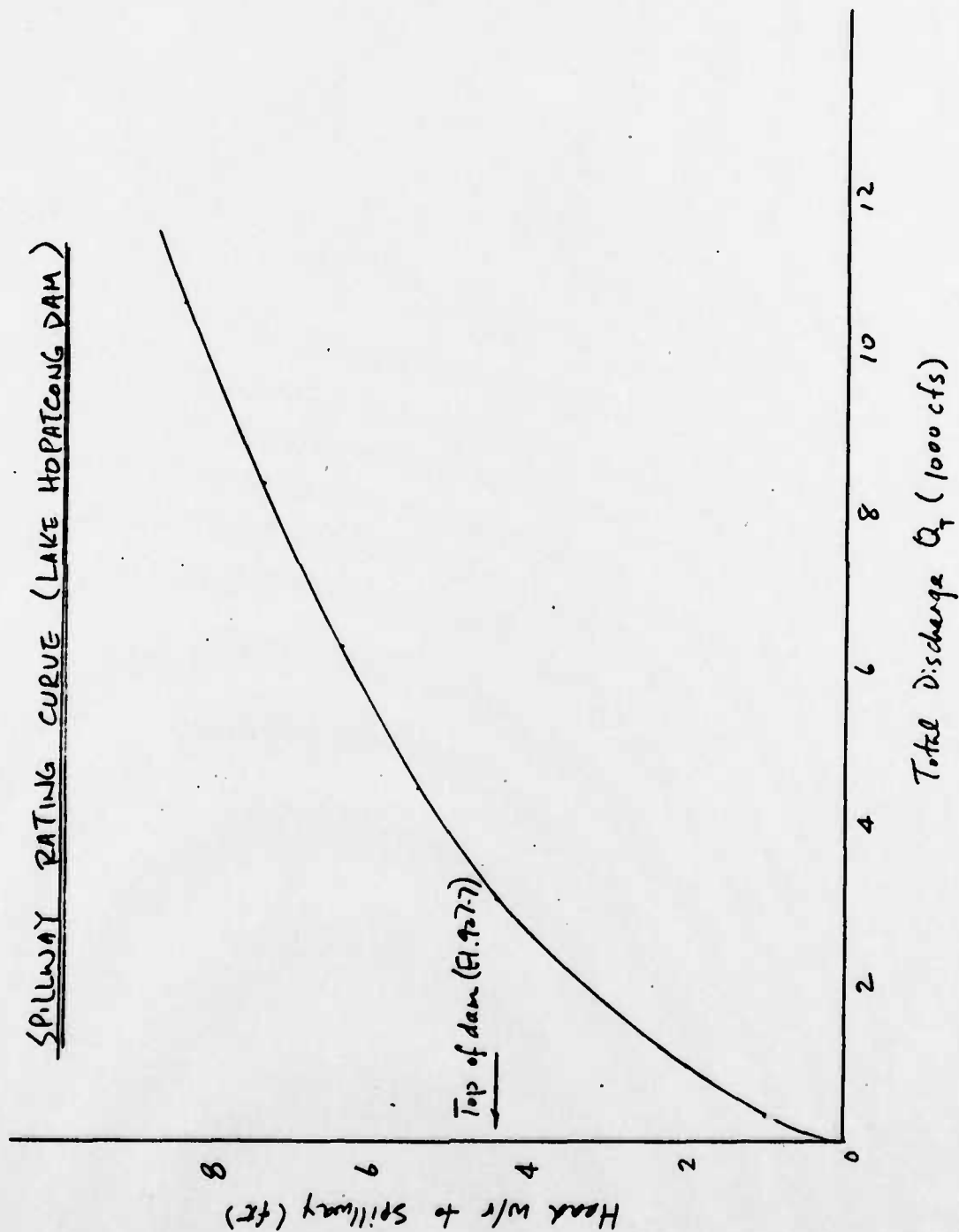
$$Q_{LE} = 108 \text{ ft}^3/\text{s}$$

BY Py DATE 1-21-79
CKD SPD DATE 3-29-79

Lake Hartman Dam

JOB NO. J-743 B

SHEET NO. 6 OF 12



BY Py

DATE 1-31-79
3-16-79

Lake Hopatcong Dam

JOB NO. T-763B

CKD Py

DATE 2-29-79

SHEET NO. 7 OF 12

Reservoir Storage Capacity

Assume a linear distribution for the area of the lake with elevation. Start at a zero storage at the crest of the spillway

Area of Lake = 2474 acres

Perimeter of Lake = 3.5 mi = 184800 ft. (Estimated)

Since the perimeter of the lake is estimated to the nearest mile, \therefore for estimated analysis purpose, it is assumed to be constant within the working elevation range.

Assume average side slope of lake = 1V: 4H.

\therefore for every foot of water above the crest of spillway the area of the lake increases by approximately $\frac{4(184800)}{43560} = 17$ Acres

| Elev. (ft) | H (ft) | Increase in Lake Area (Acres) | Area of Lake (Acres) |
|---------------|-----------|----------------------------------|-------------------------|
| 923.3 | 0 | | 2474 |
| 924.3 | 1 | 17 | 2491 |
| 925.3 | 2 | 34 | 2508 |
| 926.3 | 3 | 51 | 2525 |
| 927.3 | 4 | 68 | 2542 |
| 928.3 | 5 | 85 | 2559 |
| 929.3 | 6 | 102 | 2576 |
| 930.3 | 7 | 119 | 2593 |
| 931.3 | 8 | 136 | 2610 |
| 932.3 | 9 | 153 | 2627 |
| 933.3 | 10 | 170 | 2644 |
| 934.3 | 11 | 187 | 2661 |

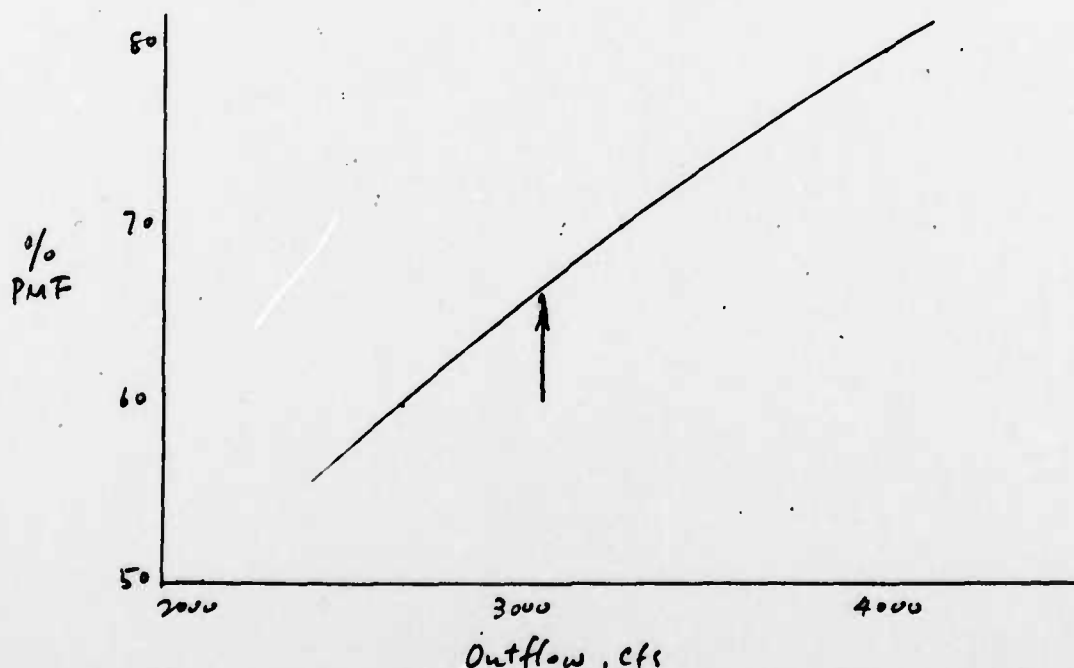
BY PyDATE 1-30-79Lake Hopatcong DamJOB NO. 5-783 BCKD GedDATE 3-27-79SHEET NO. 8 OF 12

SUMMARY OF HYDROGRAPH AND FLOOD ROUTING

1. Hydrograph and routing calculated using HEC-1
2. PMF peak inflow for Lake Hopatcong is 15026 cfs
(routed to 5640 cfs)
3. Routing indicates the earth embankment on both end of the spillway will overtop by approximately 1.6 ft for PMF.

OVERTOPPING POTENTIAL

1. Various % of PMF have been routed using HEC-1
2. Plot peak outflow vs % PMF



3. Dam overtops at approx El. 9.7 with $Q = 3073$ cfs (gates closed)
 \therefore dam can pass approx. 66% of PMF.

DRAWDOWN ANALYSIS

1. Outlet structure

4 - 3'x5' sluice gates

(The discharge from the fountain is insignificant.)
∴ not considered in the analysis

2. Outlet capacity

Sill of gates at El. 911.7

∴ Top of gates at El. 916.7

When pool elevation is above El. 916.7, discharge is governed by orifice flow. As pool elevation is lowered below El. 916.7, discharge is governed by weir flow. Use $C = 3.33$ for weir flow and $C = 0.623$ (see sheet No. 4) for orifice flow

| | Elev. (ft) | Head (ft) | Q (cfs) | Q out avg. (cfs) |
|----------------|------------|-----------|---------|------------------|
| Orifice flow ↑ | 923.3 | 9 | 900 | 858 |
| | 921.7 | 7.4 | 816 | 757 |
| | 919.7 | 5.4 | 697 | 625 |
| | 917.7 | 3.4 | 553 | 500 |
| | 916.7 | 5 | 447 | 328 |
| Weir flow ↓ | 914.7 | 3 | 208 | 124 |
| | 912.7 | 1 | 40 | 20 |
| | 911.7 | 0 | 0 | |
| | | | | |

$$Q_o = 0.623(60)\sqrt{2gh} = 37\sqrt{2gh}$$

$$Q_w = 3.33(12)H^{1.5} = 40H^{1.5}$$

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3. Storage Capacity

a. Usable volume above lowest gate
 = 800,000,000 cu.ft. (available data)
 = 18365 Ac.ft

b. Assume area varies linearly with height
 then area of lake at bottom of gates
 = $\frac{18365 \times 2}{11.6} - 2474 = 692$ Ac.

| <u>Elev. (ft)</u> | <u>Area (Ac)</u> | <u>Δ Storage (ac-ft)</u> | <u>Total Storage (Ac-ft)</u> |
|-------------------|------------------|--------------------------|------------------------------|
| 923.3 | 2474 | 3762 | 18365 |
| 921.7 | 2228 | 4149 | |
| 919.7 | 1921 | 3535 | |
| 917.7 | 1614 | 1537 | |
| 916.7 | 1460 | 2613 | |
| 914.7 | 1153 | 1999 | |
| 912.7 | 846 | 769 | |
| 911.7 | 692 | | |

BY Py

DATE 6-31-79

Lake Hualacang Dam

JOB NO. J-7838

CKD ED

DATE 3-29-79

SHEET NO. 11 OF 12

4. Assume inflow to be 2 cfs/sq. mi

$$Q_{in} = 2 \times 25.4 = 50.8 \text{ cfs.} \approx 51 \text{ cfs}$$

| Elev. (ft) | $Q_{out, avg}$ (cfs) | Q_{net}^* (cfs) | $\Delta \text{storage}$ (Ac.-ft) | Δt (hr.) | $\Sigma \Delta t$ (hr.) | |
|------------|----------------------|-------------------|-------------------------------------|------------------|-------------------------|---------|
| 923.3 | 858 | 807 | 3762 | 56.4 | 56.4 | |
| 921.7 | 757 | 706 | 4149 | 71.1 | 127.5 | |
| 919.7 | 625 | 574 | 3535 | 74.5 | 202.0 | |
| 917.7 | 500 | 449 | 1537 | 41.4 | 243.4 | 10 days |
| 916.7 | 328 | 277 | 2613 | 114.1 | 357.5 | — |
| 914.7 | 124 | 73 | 1999 | 331.3 | 688.8 | 29 days |
| 912.7 | 20 | —** | | | | |
| 911.7 | | | | | | |

$$* Q_{net} = Q_{out, avg} - Q_{in} = Q_{out, avg} - 51$$

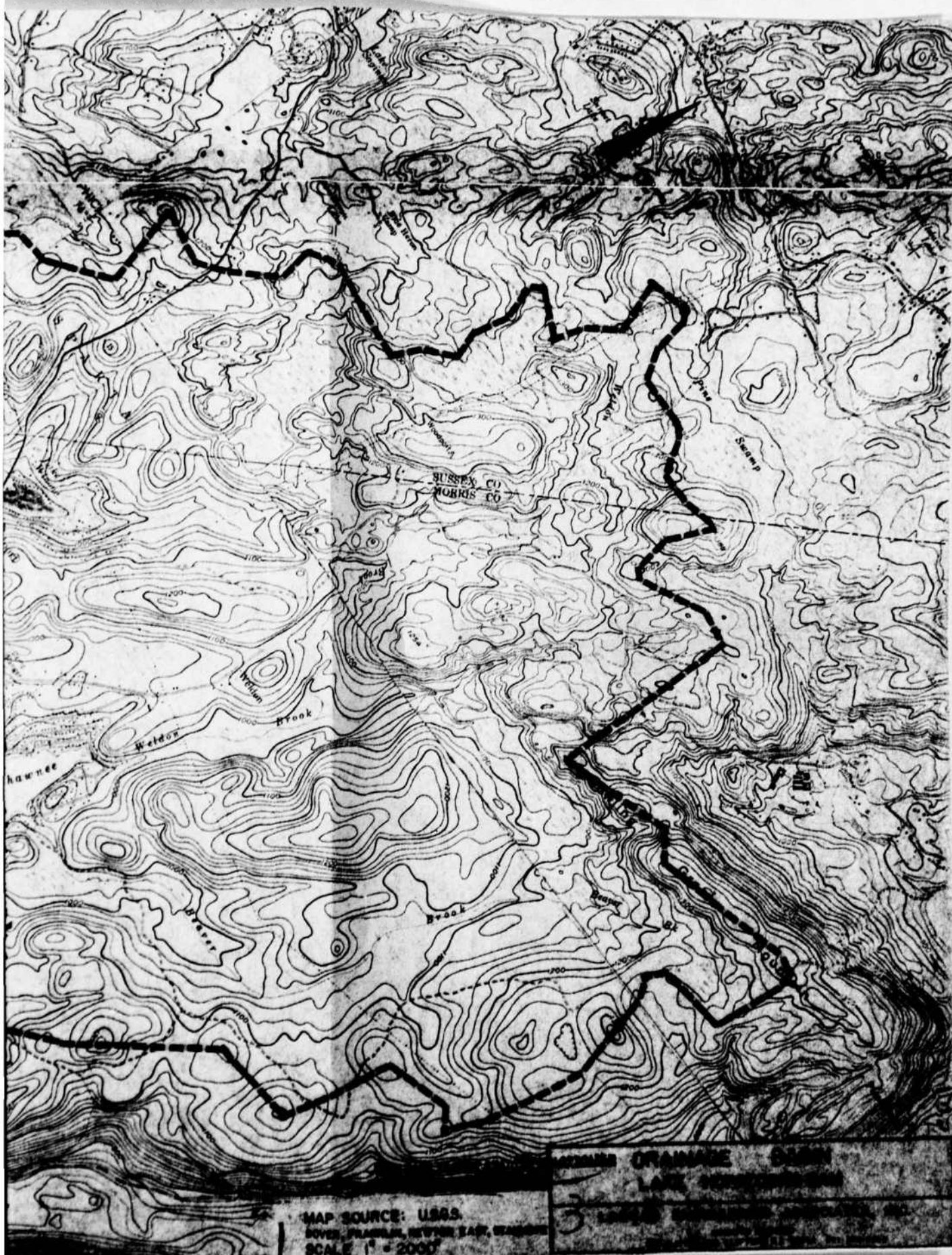
** Inflow > Outflow, \therefore not considered

Conclusion: We estimate that the reservoir can be lowered 7 feet in about 10 days and 11 feet in about 29 days

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MAP SOURCE: USGS.
DOVER, FRANKLIN, NEWTON, EAST, WASHINGTON
SCALE 1" = 2000'

3-10000-10000
3-10000-10000
3-10000-10000

HEC-1 OUTPUT

LAKE HOPATCONG LAKE DAM

INP0UT1 16:40 FEB 01.'79

1.....
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 25 SEP 78
.....

| | LAKE IOPATCONG DAM INFLOW HYDROGRAPH AND ROUTING N.J. DAM INSPECTION | | | | | | | | | |
|---------|--|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 A | | | | | | | | | | |
| 2 A | | | | | | | | | | |
| 3 A | | | | | | | | | | |
| 4 B | 150 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 B1 | 3 | | | | | | | | | |
| 6 K | | 1 | | | | | | | | |
| 7 K1 | COMPUTE HYDROGRAPH | | | | | | | | | |
| 8 M | 1 | 1 | 25.4 | | 0.82 | | | | | |
| 9 P | 22.4 | 104 | 113 | 123 | 135 | | | | | |
| 10 T | | | | | | 1 | .15 | | | |
| 11 W | 12.0 | 0.58 | | | | | | | | |
| 12 X | -2 | | 1 | | | | | | | |
| 13 K | 1 | 2 | | | | | | | | |
| 14 K1 | ROUTING COMPUTATIONS | | | | | | | | | |
| 15 Y | | | | | | 1 | | | | |
| 16 Y1 | 1 | | | | | | | | | |
| 17 Y4 | 923.3 | 924.3 | 925.3 | 926.3 | 927.7 | 928.7 | 929.7 | 930.7 | 931.7 | |
| 18 Y5 | 0 | 333 | 942 | 1730 | 3073 | 4497 | 6291 | 8355 | 10651 | |
| 19 \$A | 2474 | 2491 | 2508 | 2525 | 2542 | 2559 | 2576 | 2593 | 2610 | 2627 |
| 20 \$A | 2644 | 2661 | | | | | | | | |
| 21 \$E | 923.3 | 924.3 | 925.3 | 926.3 | 927.3 | 928.3 | 929.3 | 930.3 | 931.3 | 932.3 |
| 22 \$E | 933.3 | 934.3 | | | | | | | | |
| 23 \$\$ | 923.3 | | | | | | | | | |
| 24 \$D | 927.7 | | | | | | | | | |
| 25 K | 99 | | | | | | | | | |

PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

| RUNOFF HYDROGRAPH AT | 1 |
|----------------------|---|
| ROUTE HYDROGRAPH TO | 2 |
| END OF NETWORK | |

1.....
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 25 SEP 78
.....

RUN DATE: 79/02/01.
TIME: 15.07.26.

LAKE HOPATCONG DAM
INFLOW HYDROGRAPH AND ROUTING
N.J. DAM INSPECTION

| JOB SPECIFICATION | | | | | | | | | |
|-------------------|-----|------|-------|-----|-------|-------|------|------|-------|
| NQ | NHR | NMIN | IDAY | IHR | IMIN | METRC | IPLT | IPRT | NSTAN |
| 150 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | JOPER | NWT | LROPT | TRACE | | | |
| | | | 3 | 0 | 0 | 0 | | | |

SUB-AREA RUNOFF COMPUTATION

COMPUTE HYDROGRAPH

| ISTAQ | ICOMP | IECON | ITAPE | JPLT | JPRT | INAME | ISTAGE | IAUTO |
|-------|-------|-------|-------|------|------|-------|--------|-------|
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |

| HYDROGRAPH DATA | | | | | | | | | |
|-----------------|------|-------|------|-------|-------|-------|-------|-------|-------|
| IHYDG | IUNG | TAREA | SNAP | TRSDA | TRSPC | RATIO | ISNOW | ISAME | LOCAL |
| 1 | 1 | 25.40 | 0.00 | 25.40 | .82 | 0.000 | 0 | 0 | 0 |

| PRECIP DATA | | | | | | | | | |
|-------------|-------|--------|--------|--------|--------|------|------|--|--|
| SPFE | PMS | R6 | R12 | R24 | R48 | R72 | R96 | | |
| 0.00 | 22.40 | 104.00 | 113.00 | 123.00 | 135.00 | 0.00 | 0.00 | | |

| LOSS DATA | | | | | | | | | | |
|-----------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| LROPT | STKR | DLTKR | RTIOL | ERAIN | STRKS | RTIOK | STRTL | CNSTL | ALSMX | RTIMP |
| 0 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1.00 | 1.00 | .15 | 0.00 | 0.00 |

UNIT HYDROGRAPH DATA
TP= 12.00 CP= .58 NTA= 0

APPROXIMATE CLARE COEFFICIENTS FROM GIVEN SNYDER CP AND TP ARE TC=12.98 AND R=12.76 INTERVALS

| RECESSION DATA | | | | | | | | | | |
|----------------|-------|--------|------|--------|------|------|------|------|------|--|
| STRTQ= | -2.00 | ORCSN= | 0.00 | RTIOR= | 1.00 | | | | | |
| 19. | 70. | 143. | 229. | 323. | 424. | 528. | 624. | 701. | 760. | |
| 799. | 817. | 807. | 764. | 707. | 653. | 604. | 559. | 517. | 478. | |
| 442. | 408. | 378. | 349. | 323. | 298. | 276. | 255. | 236. | 218. | |
| 202. | 186. | 172. | 159. | 147. | 136. | 126. | 117. | 108. | 100. | |
| 92. | 85. | 79. | 73. | 67. | 62. | 58. | 53. | 49. | 45. | |
| 42. | 39. | 36. | 33. | 31. | 28. | 26. | 24. | 22. | 21. | |
| 19. | 18. | 16. | 15. | 14. | 13. | 12. | 11. | 10. | 9. | |

| MO.DA | | HR.MN | PERIOD | RAIN | EXCS | LOSS | END-OF-PERIOD FLOW | | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q | |
|-------|-------|-------|--------|------|------|------|--------------------|-------|-------|--------|------|------|------|--------|--------|
| MO.DA | | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q | MO.DA | HR.MN | PERIOD | RAIN | EXCS | LOSS | COMP Q | COMP Q |
| 1.01 | 1.00 | 1.00 | 1 | .01 | 0.00 | .01 | 51. | 1.04 | 4.00 | 76 | 0.00 | 0.00 | 0.00 | 2411. | 2411. |
| 1.01 | 2.00 | 2.00 | 2 | .01 | 0.00 | .01 | 51. | 1.04 | 5.00 | 77 | 0.00 | 0.00 | 0.00 | 2233. | 2233. |
| 1.01 | 3.00 | 3.00 | 3 | .01 | 0.00 | .01 | 51. | 1.04 | 6.00 | 78 | 0.00 | 0.00 | 0.00 | 2068. | 2068. |
| 1.01 | 4.00 | 4.00 | 4 | .01 | 0.00 | .01 | 51. | 1.04 | 7.00 | 79 | 0.00 | 0.00 | 0.00 | 1916. | 1916. |
| 1.01 | 5.00 | 5.00 | 5 | .01 | 0.00 | .01 | 51. | 1.04 | 8.00 | 80 | 0.00 | 0.00 | 0.00 | 1776. | 1776. |
| 1.01 | 6.00 | 6.00 | 6 | .01 | 0.00 | .01 | 51. | 1.04 | 9.00 | 81 | 0.00 | 0.00 | 0.00 | 1646. | 1646. |
| 1.01 | 7.00 | 7.00 | 7 | .03 | 0.00 | .03 | 51. | 1.04 | 10.00 | 82 | 0.00 | 0.00 | 0.00 | 1525. | 1525. |
| 1.01 | 8.00 | 8.00 | 8 | .03 | 0.00 | .03 | 51. | 1.04 | 11.00 | 83 | 0.00 | 0.00 | 0.00 | 1414. | 1414. |
| 1.01 | 9.00 | 9.00 | 9 | .03 | 0.00 | .03 | 51. | 1.04 | 12.00 | 84 | 0.00 | 0.00 | 0.00 | 1311. | 1311. |
| 1.01 | 10.00 | 10.00 | 10 | .03 | 0.00 | .03 | 51. | 1.04 | 13.00 | 85 | 0.00 | 0.00 | 0.00 | 1216. | 1216. |
| 1.01 | 11.00 | 11.00 | 11 | .03 | 0.00 | .03 | 51. | 1.04 | 14.00 | 86 | 0.00 | 0.00 | 0.00 | 1129. | 1129. |
| 1.01 | 12.00 | 12.00 | 12 | .03 | 0.00 | .03 | 51. | 1.04 | 15.00 | 87 | 0.00 | 0.00 | 0.00 | 1047. | 1047. |
| 1.01 | 13.00 | 13.00 | 13 | .19 | 0.00 | .19 | 51. | 1.04 | 16.00 | 88 | 0.00 | 0.00 | 0.00 | 972. | 972. |
| 1.01 | 14.00 | 14.00 | 14 | .22 | 0.00 | .22 | 51. | 1.04 | 17.00 | 89 | 0.00 | 0.00 | 0.00 | 903. | 903. |
| 1.01 | 15.00 | 15.00 | 15 | .28 | 0.00 | .28 | 51. | 1.04 | 18.00 | 90 | 0.00 | 0.00 | 0.00 | 838. | 838. |
| 1.01 | 16.00 | 16.00 | 16 | .71 | .50 | .21 | 60. | 1.04 | 19.00 | 91 | 0.00 | 0.00 | 0.00 | 776. | 776. |
| 1.01 | 17.00 | 17.00 | 17 | .26 | .11 | .15 | 88. | 1.04 | 20.00 | 92 | 0.00 | 0.00 | 0.00 | 721. | 721. |
| 1.01 | 18.00 | 18.00 | 18 | .21 | .06 | .15 | 131. | 1.04 | 21.00 | 93 | 0.00 | 0.00 | 0.00 | 670. | 670. |
| 1.01 | 19.00 | 19.00 | 19 | .02 | 0.00 | .02 | 184. | 1.04 | 22.00 | 94 | 0.00 | 0.00 | 0.00 | 623. | 623. |
| 1.01 | 20.00 | 20.00 | 20 | .02 | 0.00 | .02 | 245. | 1.04 | 23.00 | 95 | 0.00 | 0.00 | 0.00 | 580. | 580. |
| 1.01 | 21.00 | 21.00 | 21 | .02 | 0.00 | .02 | 310. | 1.05 | 0.00 | 96 | 0.00 | 0.00 | 0.00 | 540. | 540. |
| 1.01 | 22.00 | 22.00 | 22 | .02 | 0.00 | .02 | 378. | 1.05 | 1.00 | 97 | 0.00 | 0.00 | 0.00 | 503. | 503. |
| 1.01 | 23.00 | 23.00 | 23 | .02 | 0.00 | .02 | 443. | 1.05 | 2.00 | 98 | 0.00 | 0.00 | 0.00 | 469. | 469. |
| 1.02 | 0.00 | 0.00 | 24 | .02 | 0.00 | .02 | 541. | 1.05 | 3.00 | 99 | 0.00 | 0.00 | 0.00 | 438. | 438. |
| 1.02 | 1.00 | 1.00 | 25 | .12 | 0.00 | .12 | 571. | 1.05 | 4.00 | 100 | 0.00 | 0.00 | 0.00 | 409. | 409. |
| 1.02 | 2.00 | 2.00 | 26 | .12 | 0.00 | .12 | 587. | 1.05 | 5.00 | 101 | 0.00 | 0.00 | 0.00 | 382. | 382. |
| 1.02 | 3.00 | 3.00 | 27 | .12 | 0.00 | .12 | 587. | 1.05 | 6.00 | 102 | 0.00 | 0.00 | 0.00 | 357. | 357. |
| 1.02 | 4.00 | 4.00 | 28 | .12 | 0.00 | .12 | 587. | 1.05 | 7.00 | 103 | 0.00 | 0.00 | 0.00 | 334. | 334. |
| 1.02 | 5.00 | 5.00 | 29 | .12 | 0.00 | .12 | 565. | 1.05 | 8.00 | 104 | 0.00 | 0.00 | 0.00 | 312. | 312. |
| 1.02 | 6.00 | 6.00 | 30 | .12 | 0.00 | .12 | 531. | 1.05 | 9.00 | 105 | 0.00 | 0.00 | 0.00 | 293. | 293. |
| 1.02 | 7.00 | 7.00 | 31 | .28 | .13 | .15 | 498. | 1.05 | 10.00 | 106 | 0.00 | 0.00 | 0.00 | 274. | 274. |
| 1.02 | 8.00 | 8.00 | 32 | .28 | .13 | .15 | 474. | 1.05 | 11.00 | 107 | 0.00 | 0.00 | 0.00 | 256. | 256. |
| 1.02 | 9.00 | 9.00 | 33 | .28 | .13 | .15 | 461. | 1.05 | 12.00 | 108 | 0.00 | 0.00 | 0.00 | 240. | 240. |
| 1.02 | 10.00 | 10.00 | 34 | .28 | .13 | .15 | 461. | 1.05 | 13.00 | 109 | 0.00 | 0.00 | 0.00 | 225. | 225. |
| 1.02 | 11.00 | 11.00 | 35 | .28 | .13 | .15 | 475. | 1.05 | 14.00 | 110 | 0.00 | 0.00 | 0.00 | 211. | 211. |
| 1.02 | 12.00 | 12.00 | 36 | .28 | .13 | .15 | 503. | 1.05 | 15.00 | 111 | 0.00 | 0.00 | 0.00 | 198. | 198. |
| 1.02 | 13.00 | 13.00 | 37 | 1.91 | 1.76 | .15 | 578. | 1.05 | 16.00 | 112 | 0.00 | 0.00 | 0.00 | 177. | 177. |
| 1.02 | 14.00 | 14.00 | 38 | 2.29 | 2.14 | .15 | 757. | 1.05 | 17.00 | 113 | 0.00 | 0.00 | 0.00 | 154. | 154. |
| 1.02 | 15.00 | 15.00 | 39 | 2.87 | 2.72 | .15 | 1097. | 1.05 | 18.00 | 114 | 0.00 | 0.00 | 0.00 | 131. | 131. |
| 1.02 | 16.00 | 16.00 | 40 | 7.26 | 7.11 | .15 | 1725. | 1.05 | 19.00 | 115 | 0.00 | 0.00 | 0.00 | 82. | 82. |
| 1.02 | 17.00 | 17.00 | 41 | 2.67 | 2.52 | .15 | 2730. | 1.05 | 20.00 | 116 | 0.00 | 0.00 | 0.00 | 65. | 65. |
| 1.02 | 18.00 | 18.00 | 42 | 2.10 | 1.95 | .15 | 4062. | 1.05 | 21.00 | 117 | 0.00 | 0.00 | 0.00 | 52. | 52. |
| 1.02 | 19.00 | 19.00 | 43 | .18 | .03 | .15 | 5633. | 1.05 | 22.00 | 118 | 0.00 | 0.00 | 0.00 | 52. | 52. |
| 1.02 | 20.00 | 20.00 | 44 | .18 | .03 | .15 | 7335. | 1.05 | 23.00 | 119 | 0.00 | 0.00 | 0.00 | 52. | 52. |
| 1.02 | 21.00 | 21.00 | 45 | .18 | .03 | .15 | 9074. | 1.06 | 0.00 | 120 | 0.00 | 0.00 | 0.00 | 52. | 52. |
| 1.02 | 22.00 | 22.00 | 46 | .18 | .03 | .15 | 10763. | 1.06 | 1.00 | 121 | 0.00 | 0.00 | 0.00 | 51. | 51. |

| | QLOSS | CROSS | AUG | ROUTING DATA | LAG | AMSKK | X | TSK | STORA | ISPRAT | LAUW |
|---------------|----------------|-----------------|--------|--------------|---------|---------|---------|---------|----------|--------|------|
| STAGE | 923.30 | 924.30 | 925.30 | 926.30 | 927.70 | 928.70 | 929.70 | 930.70 | 931.70 | | |
| FLOW | 0.00 | 333.00 | 942.00 | 1730.00 | 3073.00 | 4497.00 | 6291.00 | 8355.00 | 10651.00 | | |
| SURFACE AREA= | 2474. 2644. | 2491. 2661. | 2508. | 2525. | 2542. | 2559. | 2576. | 2593. | 2610. | 2627. | |
| CAPACITY= | 0. 25590. | 2482. 28242. | 4982. | 7498. | 10032. | 12582. | 15150. | 17734. | 20336. | 22954. | |
| ELEVATION= | 923. | 924. | 925. | 926. | 927. | 928. | 929. | 930. | 931. | 932. | |

| CREL 923.3 | SPWID 0.0 | COOW 0.0 | EXPW 0.0 | ELEV 0.0 | COOL 0.0 | CAREA 0.0 | EXPL 0.0 | END-OF-PERIOD HYDROGRAPH ORDINATES | | | | STAGE |
|---------------|--------------|-------------|----------------|-------------|-------------|--------------|-------------|------------------------------------|---------|-----------------|---------|-------|
| | | | | | | | | NO.DA | HR.MN | PERIOD HOURS | STORAGE | |
| | | | | | | | | | | | | |
| | | | TOPEL 927.7 | DAM DATA | | | | | | | | |
| | | | | COOL | EXPD | DAMWID | | INFLOW | OUTFLOW | | | |
| 1.01 | 1.00 | 1 | 1.00 | 51. | | | | 1. | | 4. | | |
| 1.01 | 2.00 | 2 | 2.00 | 51. | | | | 1. | | 8. | | |
| 1.01 | 3.00 | 3 | 3.00 | 51. | | | | 2. | | 12. | | |
| 1.01 | 4.00 | 4 | 4.00 | 51. | | | | 2. | | 16. | | |
| 1.01 | 5.00 | 5 | 5.00 | 51. | | | | 3. | | 20. | | |
| 1.01 | 6.00 | 6 | 6.00 | 51. | | | | 3. | | 24. | | |
| 1.01 | 7.00 | 7 | 7.00 | 51. | | | | 4. | | 28. | | |
| 1.01 | 8.00 | 8 | 8.00 | 51. | | | | 4. | | 32. | | |
| 1.01 | 9.00 | 9 | 9.00 | 51. | | | | 5. | | 36. | | |
| 1.01 | 10.00 | 10 | 10.00 | 51. | | | | 5. | | 40. | | |
| 1.01 | 11.00 | 11 | 11.00 | 51. | | | | 6. | | 43. | | |
| 1.01 | 12.00 | 12 | 12.00 | 51. | | | | 6. | | 47. | | |
| 1.01 | 13.00 | 13 | 13.00 | 51. | | | | 7. | | 51. | | |
| 1.01 | 14.00 | 14 | 14.00 | 51. | | | | 7. | | 54. | | |
| 1.01 | 15.00 | 15 | 15.00 | 51. | | | | 8. | | 58. | | |
| 1.01 | 16.00 | 16 | 16.00 | 60. | | | | 8. | | 62. | | |
| 1.01 | 17.00 | 17 | 17.00 | 88. | | | | 9. | | 67. | | |
| 1.01 | 18.00 | 18 | 18.00 | 131. | | | | 10. | | 76. | | |
| 1.01 | 19.00 | 19 | 19.00 | 184. | | | | 12. | | 88. | | |
| 1.01 | 20.00 | 20 | 20.00 | 253. | | | | | | | | |

1.04 49.00 20 21 21.00 243. 14. 104. 923.1
1.01 21.00 22 22 22.00 310. 17. 126. 923.4
1.01 22.00 23 23 23.00 378. 21. 153. 923.4
1.01 23.00 24 24 24.00 443. 25. 185. 923.4
1.02 0.00 25 25 25.00 498. 30. 221. 923.4
1.02 1.00 26 26 26.00 541. 35. 262. 923.4
1.02 2.00 27 27 27.00 571. 41. 305. 923.4
1.02 3.00 28 28 28.00 587. 47. 349. 923.4
1.02 4.00 29 29 29.00 587. 53. 393. 923.5
1.02 5.00 30 30 30.00 565. 59. 436. 923.5
1.02 6.00 31 31 31.00 531. 64. 476. 923.5
1.02 7.00 32 32 32.00 498. 69. 513. 923.5
1.02 8.00 33 33 33.00 474. 74. 548. 923.5
1.02 9.00 34 34 34.00 461. 78. 580. 923.5
1.02 10.00 35 35 35.00 461. 82. 611. 923.5
1.02 11.00 36 36 36.00 475. 86. 643. 923.6
1.02 12.00 37 37 37.00 503. 91. 676. 923.6
1.02 13.00 38 38 38.00 578. 96. 713. 923.6
1.02 14.00 39 39 39.00 757. 102. 760. 923.6
1.02 15.00 40 40 40.00 1097. 111. 828. 923.6
1.02 16.00 41 41 41.00 1725. 126. 935. 923.7
1.02 17.00 42 42 42.00 2730. 149. 1107. 923.7
1.02 18.00 43 43 43.00 4062. 185. 1374. 923.9
1.02 19.00 44 44 44.00 5633. 236. 1758. 924.0
1.02 20.00 45 45 45.00 7335. 305. 2271. 924.2
1.02 21.00 46 46 46.00 9074. 440. 2918. 924.5
1.02 22.00 47 47 47.00 10763. 629. 3694. 924.8
1.02 23.00 48 48 48.00 12283. 846. 4585. 925.1
1.03 0.00 49 49 49.00 13526. 1127. 5570. 925.5
1.03 1.00 50 50 50.00 14425. 1455. 6619. 926.0
1.03 2.00 51 51 51.00 14928. 1805. 7697. 926.4
1.03 3.00 52 52 52.00 15026. 2212. 8769. 926.8
1.03 4.00 53 53 53.00 14725. 2601. 9799. 927.2
1.03 5.00 54 54 54.00 14055. 2963. 10758. 927.6
1.03 6.00 55 55 55.00 13170. 3392. 11621. 927.9
1.03 7.00 56 56 56.00 12236. 3811. 12373. 928.2
1.03 8.00 57 57 57.00 11334. 4169. 13017. 928.5
1.03 9.00 58 58 58.00 10495. 4472. 13562. 928.7
1.03 10.00 59 59 59.00 9716. 4782. 14015. 928.9
1.03 11.00 60 60 60.00 8992. 5038. 14382. 929.0
1.03 12.00 61 61 61.00 8321. 5241. 14673. 929.1
1.03 13.00 62 62 62.00 7698. 5396. 14895. 929.2
1.03 14.00 63 63 63.00 7121. 5509. 15057. 929.3
1.03 15.00 64 64 64.00 6588. 5584. 15165. 929.3
1.03 16.00 65 65 65.00 6095. 5626. 15226. 929.3
1.03 17.00 66 66 66.00 5640. 5640. 15245. 929.3
1.03 18.00 67 67 67.00 5218. 5628. 15228. 929.3
1.03 19.00 68 68 68.00 4829. 5594. 15180. 929.3
1.03 20.00 69 69 69.00 4469. 5541. 15104. 929.3
1.03 21.00 70 70 70.00 4136. 5472. 15004. 929.2
1.03 22.00 3828. 5389. 14885. 929.2

| | | | | | | | |
|------|-------|-----|--------|-------|-------|--------|-------|
| 1.03 | 45.00 | 71 | 71.00 | 3545. | 5295. | 14748. | 929.1 |
| 1.04 | 0.00 | 72 | 72.00 | 3280. | 5188. | 14597. | 929.1 |
| 1.04 | 1.00 | 73 | 73.00 | 3036. | 5074. | 14434. | 929.0 |
| 1.04 | 2.00 | 74 | 74.00 | 2811. | 4954. | 14261. | 929.0 |
| 1.04 | 3.00 | 75 | 75.00 | 2603. | 4828. | 14080. | 928.9 |
| 1.04 | 4.00 | 76 | 76.00 | 2411. | 4697. | 13894. | 928.8 |
| 1.04 | 5.00 | 77 | 77.00 | 2233. | 4564. | 13703. | 928.7 |
| 1.04 | 6.00 | 78 | 78.00 | 2068. | 4442. | 13509. | 928.7 |
| 1.04 | 7.00 | 79 | 79.00 | 1916. | 4332. | 13311. | 928.6 |
| 1.04 | 8.00 | 80 | 80.00 | 1776. | 4221. | 13110. | 928.5 |
| 1.04 | 9.00 | 81 | 81.00 | 1646. | 4108. | 12907. | 928.4 |
| 1.04 | 10.00 | 82 | 82.00 | 1525. | 3995. | 12703. | 928.3 |
| 1.04 | 11.00 | 83 | 83.00 | 1414. | 3881. | 12500. | 928.3 |
| 1.04 | 12.00 | 84 | 84.00 | 1311. | 3768. | 12296. | 928.2 |
| 1.04 | 13.00 | 85 | 85.00 | 1216. | 3655. | 12094. | 928.1 |
| 1.04 | 14.00 | 86 | 86.00 | 1129. | 3544. | 11893. | 928.0 |
| 1.04 | 15.00 | 87 | 87.00 | 1047. | 3433. | 11695. | 928.0 |
| 1.04 | 16.00 | 88 | 88.00 | 972. | 3324. | 11499. | 927.9 |
| 1.04 | 17.00 | 89 | 89.00 | 903. | 3216. | 11306. | 927.8 |
| 1.04 | 18.00 | 90 | 90.00 | 838. | 3110. | 11117. | 927.7 |
| 1.04 | 19.00 | 91 | 91.00 | 776. | 3028. | 10930. | 927.7 |
| 1.04 | 20.00 | 92 | 92.00 | 721. | 2958. | 10744. | 927.6 |
| 1.04 | 21.00 | 93 | 93.00 | 670. | 2889. | 10560. | 927.5 |
| 1.04 | 22.00 | 94 | 94.00 | 623. | 2820. | 10378. | 927.4 |
| 1.04 | 23.00 | 95 | 95.00 | 580. | 2752. | 10197. | 927.4 |
| 1.05 | 0.00 | 96 | 96.00 | 540. | 2684. | 10019. | 927.3 |
| 1.05 | 1.00 | 97 | 97.00 | 503. | 2618. | 9843. | 927.2 |
| 1.05 | 2.00 | 98 | 98.00 | 469. | 2553. | 9670. | 927.2 |
| 1.05 | 3.00 | 99 | 99.00 | 438. | 2488. | 9499. | 927.1 |
| 1.05 | 4.00 | 100 | 100.00 | 409. | 2424. | 9331. | 927.0 |
| 1.05 | 5.00 | 101 | 101.00 | 382. | 2362. | 9166. | 927.0 |
| 1.05 | 6.00 | 102 | 102.00 | 357. | 2301. | 9004. | 926.9 |
| 1.05 | 7.00 | 103 | 103.00 | 334. | 2240. | 8844. | 926.8 |
| 1.05 | 8.00 | 104 | 104.00 | 312. | 2181. | 8688. | 926.8 |
| 1.05 | 9.00 | 105 | 105.00 | 293. | 2123. | 8536. | 926.7 |
| 1.05 | 10.00 | 106 | 106.00 | 274. | 2067. | 8386. | 926.7 |
| 1.05 | 11.00 | 107 | 107.00 | 256. | 2011. | 8239. | 926.6 |
| 1.05 | 12.00 | 108 | 108.00 | 240. | 1957. | 8096. | 926.5 |
| 1.05 | 13.00 | 109 | 109.00 | 225. | 1903. | 7955. | 926.5 |
| 1.05 | 14.00 | 110 | 110.00 | 211. | 1851. | 7818. | 926.4 |
| 1.05 | 15.00 | 111 | 111.00 | 198. | 1801. | 7684. | 926.4 |
| 1.05 | 16.00 | 112 | 112.00 | 177. | 1751. | 7553. | 926.3 |
| 1.05 | 17.00 | 113 | 113.00 | 154. | 1707. | 7424. | 926.3 |
| 1.05 | 18.00 | 114 | 114.00 | 131. | 1667. | 7296. | 926.2 |
| 1.05 | 19.00 | 115 | 115.00 | 82. | 1627. | 7169. | 926.2 |
| 1.05 | 20.00 | 116 | 116.00 | 65. | 1587. | 7042. | 926.1 |
| 1.05 | 21.00 | 117 | 117.00 | 52. | 1549. | 6917. | 926.1 |
| 1.05 | 22.00 | 118 | 118.00 | 52. | 1510. | 6795. | 926.0 |
| 1.05 | 23.00 | 119 | 119.00 | 52. | 1473. | 6676. | 926.0 |
| 1.06 | 0.00 | 120 | 120.00 | 52. | 1437. | 6560. | 925.9 |
| 1.06 | 1.00 | 121 | 121.00 | 51. | 1401. | 6447. | 925.9 |

| | | | | | | | |
|------|-------|-----|--------|-----|-------|-------|-------|
| 1.06 | 4.00 | 122 | 124.00 | 51. | 1367. | 6337. | 925.8 |
| 1.06 | 3.00 | 123 | 123.00 | 51. | 1333. | 6230. | 925.8 |
| 1.06 | 4.00 | 124 | 124.00 | 51. | 1301. | 6125. | 925.8 |
| 1.06 | 5.00 | 125 | 125.00 | 51. | 1269. | 6023. | 925.7 |
| 1.06 | 6.00 | 126 | 126.00 | 51. | 1238. | 5924. | 925.7 |
| 1.06 | 7.00 | 127 | 127.00 | 51. | 1207. | 5827. | 925.6 |
| 1.06 | 8.00 | 128 | 128.00 | 51. | 1178. | 5733. | 925.6 |
| 1.06 | 9.00 | 129 | 129.00 | 51. | 1149. | 5641. | 925.6 |
| 1.06 | 10.00 | 130 | 130.00 | 51. | 1121. | 5551. | 925.5 |
| 1.06 | 11.00 | 131 | 131.00 | 51. | 1093. | 5464. | 925.5 |
| 1.06 | 12.00 | 132 | 132.00 | 51. | 1067. | 5379. | 925.5 |
| 1.06 | 13.00 | 133 | 133.00 | 51. | 1041. | 5296. | 925.4 |
| 1.06 | 14.00 | 134 | 134.00 | 51. | 1015. | 5215. | 925.4 |
| 1.06 | 15.00 | 135 | 135.00 | 51. | 991. | 5136. | 925.4 |
| 1.06 | 16.00 | 136 | 136.00 | 51. | 966. | 5060. | 925.3 |
| 1.06 | 17.00 | 137 | 137.00 | 51. | 943. | 4985. | 925.3 |
| 1.06 | 18.00 | 138 | 138.00 | 51. | 925. | 4912. | 925.3 |
| 1.06 | 19.00 | 139 | 139.00 | 51. | 908. | 4841. | 925.2 |
| 1.06 | 20.00 | 140 | 140.00 | 51. | 891. | 4770. | 925.2 |
| 1.06 | 21.00 | 141 | 141.00 | 51. | 874. | 4702. | 925.2 |
| 1.06 | 22.00 | 142 | 142.00 | 51. | 858. | 4634. | 925.2 |
| 1.06 | 23.00 | 143 | 143.00 | 51. | 842. | 4568. | 925.1 |
| 1.07 | 0.00 | 144 | 144.00 | 51. | 826. | 4504. | 925.1 |
| 1.07 | 1.00 | 145 | 145.00 | 51. | 810. | 4440. | 925.1 |
| 1.07 | 2.00 | 146 | 146.00 | 51. | 795. | 4378. | 925.1 |
| 1.07 | 3.00 | 147 | 147.00 | 51. | 780. | 4317. | 925.0 |
| 1.07 | 4.00 | 148 | 148.00 | 51. | 766. | 4258. | 925.0 |
| 1.07 | 5.00 | 149 | 149.00 | 51. | 752. | 4199. | 925.0 |
| 1.07 | 6.00 | 150 | 150.00 | 51. | 738. | 4142. | 925.0 |

PEAK OUTFLOW IS 5640. AT TIME 65.00 HOURS

| | PEAK | 6-HOUR | 24-HOUR | 72-HOUR | TOTAL VOLUME |
|------------|-------|--------|---------|---------|--------------|
| CPS | 5640. | 5600. | 5103. | 3406. | 280676. |
| CMS | 160. | 159. | 145. | 96. | 7948. |
| INCHES | | 2.05 | 7.48 | 14.97 | 17.13 |
| MM | | 52.09 | 189.89 | 380.21 | 435.16 |
| AC-FT | | 2777. | 10122. | 20268. | 23196. |
| THOUS CU M | | 3425. | 12486. | 25000. | 28612. |

RUNOFF SUMMARY, AVERAGE FLOW IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

| HYDROGRAPH AT | ROUTED TO | PEAK | | | | AREA | |
|---------------|-----------|------------|------------|------------|------------|------------|-----------|
| | | 1 | 2 | 6-HOUR | 24-HOUR | 72-HOUR | AREA |
| | | 15026. | 5640. | 14418. | 10167. | 4450. | 25.40 |
| | | (425.48) | (159.70) | (408.27) | (287.88) | (126.02) | (65.79) |
| | | | | 5600. | 5103. | 3406. | 25.40 |
| | | | | (158.56) | (144.51) | (96.45) | (65.79) |

SUMMARY OF DAM SAFETY ANALYSIS

| PLAN 1 | | ELEVATION | | INITIAL VALUE | | SPILLWAY CREST | | TOP OF DAM | |
|--------------------|----------------------------------|------------------------------|-----------------------------|---------------------------|-------------------------------|---------------------------------|-----------------------------|------------|--|
| | | STORAGE | | 923.30 | | 923.30 | | 927.70 | |
| | | OUTFLOW | | 0. | | 0. | | 11050. | |
| | | | | 0. | | 0. | | 3073. | |
| RATIO OF PMF | MAXIMUM RESERVOIR W.S.ELEV | MAXIMUM DEPTH OVER DAM | MAXIMUM STORAGE AC-FT | MAXIMUM OUTFLOW CFS | DURATION OVER TOP HOURS | TIME OF MAX OUTFLOW HOURS | TIME OF FAILURE HOURS | | |
| | | | | | | | | | |
| 0.00 | 929.34 | 1.64 | 15245. | 5640. | 37.00 | 65.00 | 0.00 | | |

1.....
 FLOOD HYDROGRAPH PACKAGE (HEC-1)
 DAM SAFETY VERSION JULY 1978
 LAST MODIFICATION 25 SEP 78

REPORT 17:05 FEB 01, '79

FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 25 SEP 78

PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

RUNOFF HYDROGRAPH AT 1
ROUTE HYDROGRAPH TO 2
END OF NETWORK

FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 25 SEP 78

RUN DATE# 79/02/01.
TIME# 15.28.39.

LAKE HOPATCONG DAM
INFLOW HYDROGRAPH AND ROUTING
N.J. DAM INSPECTION

| JOB SPECIFICATION | | | | | | | | | |
|-------------------|-----|------|-------|-----|-------|-------|------|------|-------|
| NQ | NHR | NMIN | IDAY | IHR | IMIN | METRC | IPLT | IPRT | NSTAN |
| 150 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| | | | JOPER | NWT | LROPT | TRACE | | | |
| | | | 5 | 0 | 0 | 0 | | | |

MULTI-PLAN ANALYSES TO BE PERFORMED
RTIOS= 1.00 .90 .80 .70 .60 .50
NPLAN= 1 NRTIO= 6 LRTIO= 1

SUB-AREA RUNOFF COMPUTATION

COMPUTE HYDROGRAPH

ISTAQ ICOMP IECON ITAPE JPLT JPRT INAME ISTAGE IAUTO
1 0 0 0 0 0 1 0 0

IHYDG IUHG TAREA SNAP TRSDA TRSPC RATIO ISNOW ISAME LOCAL
1 1 25.40 0.00 25.40 .82 0.000 0 0 0 0

PRECIP DATA
SPFE PMS R6 R12 R24 R48 R72 R96
0.00 22.40 104.00 113.00 123.00 135.00 0.00 0.00

LOSS DATA
LROPT STRKR DLTKR RTIOL ERAIN STRKS RTIOK STRTL CNSTL ALSMX RTIMP
0 0.00 0.00 1.00 1.00 0.00 1.00 1.00 1.00 .15 0.00 0.00

UNIT HYDROGRAPH DATA
TP= 12.00 CP= .58 NTA= 0

RECESSION DATA
STRTOQ= -2.00 QRCSN= 0.00 RTIOR= 1.00

UNIT HYDROGRAPH 75 END-OF-PERIOD ORDINATES, LAG= 12.03 HOURS, CP= .58 VOL= 1.00
19. 70. 143. 229. 323. 424. 528. 624. 701. 760.
799. 817. 807. 764. 707. 653. 604. 559. 517. 478.
442. 408. 378. 349. 323. 298. 276. 255. 236. 218.
202. 186. 172. 159. 147. 136. 126. 117. 108. 100.
92. 85. 79. 73. 67. 62. 58. 53. 49. 45.
42. 39. 36. 31. 28. 26. 24. 22. 21. 21.
19. 18. 16. 15. 14. 13. 12. 11. 10. 9.

MO.DA IIR.MN PERIOD RAIN EXCS LOSS COMP Q END-OF-PERIOD FLOW
0 MO.DA IIR.MN PERIOD RAIN EXCS LOSS COMP Q
SUM 24.80 19.82 4.98 330800.
(630.) (503.) (126.) (9367.21)

ROUTING COMPUTATIONS

HYDROGRAPH ROUTING

ROUTING DATA

ISTAQ ICOMP IECON ITAPE JPLT JPRT INAME ISTAGE IAUTO
2 1 0 0 0 0 1 0 0
ROUTING DATA
GROSS CLOSS AVG IRES ISAME IOPT IPMP LSTR
0.0 0.000 0.00 1 0 0 0 0

| STAGE | 923.30 | 924.30 | 925.30 | 926.30 | 927.70 | 928.70 | 929.70 | 930.70 | 931.70 |
|---------------|----------------|-----------------|--------|---------|---------|---------|---------|---------|----------|
| FLOW | 0.00 | 333.00 | 942.00 | 1730.00 | 3073.00 | 4497.00 | 6291.00 | 8355.00 | 10651.00 |
| SURFACE AREA= | 2474. 2644. | 2491. 2661. | 2508. | 2525. | 2542. | 2559. | 2576. | 2610. | 2627. |
| CAPACITY= | 0. 25590. | 2482. 28242. | 4982. | 7498. | 10032. | 12582. | 15150. | 20336. | 22954. |
| ELEVATION= | 923. 933. | 924. 934. | 925. | 926. | 927. | 928. | 929. | 930. | 931. |

| | | | | | | | |
|-------|-------|------|------|------|------|-------|------|
| CREL | SPWID | COQM | EXPW | ELEV | COQL | CAREA | EXPL |
| 923.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | | | |
|-------|------|------|--------|
| TOPEL | COQD | EXPD | DAMWID |
| 927.7 | 0.0 | 0.0 | 0. |

| | | |
|-----------------|---------------|-------------|
| PEAK OUTFLOW IS | 5640. AT TIME | 65.00 HOURS |
| PEAK OUTFLOW IS | 4804. AT TIME | 66.00 HOURS |
| PEAK OUTFLOW IS | 4032. AT TIME | 66.00 HOURS |
| PEAK OUTFLOW IS | 3296. AT TIME | 67.00 HOURS |
| PEAK OUTFLOW IS | 2679. AT TIME | 68.00 HOURS |
| PEAK OUTFLOW IS | 2120. AT TIME | 69.00 HOURS |

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE KILOMETERS

OPERATION STATION AREA PLAN RATIO 1 RATIO 2 RATIO 3 RATIO 4 RATIO 5 RATIO 6

HYDROGRAPH AT 1 25.40 1 15026. 13523. 12020. 10518. 9015. 7513.
(65.79) (425.48)(382.93)(340.38)(297.83)(255.29)(212.74) (

ROUTED TO 2 25.40 1 5640. 4804. 4032. 3296. 2679. 2120.
(65.79) (159.70)(136.04)(114.18)(93.32)(75.85)(60.02) (

SUMMARY OF DAM SAFETY ANALYSIS

| PLAN 1 | ELEVATION STORAGE OUTFLOW | INITIAL VALUE 923.30 0. 0. | SPILLWAY CREST 923.30 0. 0. | TOP OF DAM 927.70 11050. 3073. | | | | | |
|--------------------|----------------------------------|-------------------------------------|--------------------------------------|---|-------------------------------|---------------------------------|-----------------------------|--|--|
| | | | | | | | | | |
| RATIO OF PMF | MAXIMUM RESERVOIR W.S.ELEV | MAXIMUM DEPTH OVER DAM | MAXIMUM STORAGE AC-FT | MAXIMUM OUTFLOW CFS | DURATION OVER TOP HOURS | TIME OF MAX OUTFLOW HOURS | TIME OF FAILURE HOURS | | |
| 1.00 | 929.34 | 1.64 | 15245. | 5640. | 37.00 | 65.00 | 0.00 | | |
| .90 | 928.87 | 1.17 | 14047. | 4804. | 32.00 | 66.00 | 0.00 | | |
| .80 | 928.37 | .67 | 12771. | 4032. | 25.00 | 66.00 | 0.00 | | |
| .70 | 927.86 | .16 | 11449. | 3296. | 13.00 | 67.00 | 0.00 | | |
| .60 | 927.29 | 0.00 | 10004. | 2679. | 0.00 | 68.00 | 0.00 | | |
| .50 | 926.71 | 0.00 | 8525. | 2120. | 0.00 | 69.00 | 0.00 | | |

FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 25 SEP 78

APPENDIX 4

REFERENCES

LAKE HOPATCONG LAKE DAM

APPENDIX 4

REFERENCES

LAKE HOPATCONG DAM

1. Letter to Dr. H.B. Kummel, Morris Canal & Banking Co., from C.C. Vermeule, Consulting Engineer, dated 22 August 1924.
2. Letter to Dr. H.B. Kummel, from C.C. Vermeule, dated 4 September 1924.
3. Report on Lake Hopatcong Dam by J.L. Weber, Hydraulic Engineer, dated 10 September 1924.
4. Specifications, Proposal, Contract and Bond for Section 60, Dam and Bridge at Lake Hopatcong, by Morris Canal and Banking Company, approx. date October 1924.
5. Monthly Progress Report by C.C. Vermeule, dated 31 October 1924.
6. Inspection Report by J.N. Brooks, Hydraulic Engineer, dated 20 November 1924.
7. Monthly Progress Report by C.C. Vermeule, dated 30 November 1924.
8. Photos of Lake Hopatcong Dam dated 22 May 1925.
9. Memorandum regarding Lake Hopatcong State Park, by H.T. Critchlow, dated 19 October 1928.
10. Letter to Mr. A. Kreiger from C.P. Wilbur, Dept. of Conservation & Development, dated 21 October 1942.
11. Annual Report on Lake Hopatcong Dam, by M. Berkowitz, dated 5 June 1968.
12. News Release by N.J. dept. of Environmental Protection, dated 15 August 1975.
13. Annual Report on Lake Hopatcong Dam, by N. Biocco, dated 23 April 1976.
14. Memorandum to Mr. A.T. Guido from J. Wilford, dated 11 May 1977.
15. Memorandum to Mr. F.E. Guidotto from A.T. Guido, dated 13 November 1978.
16. Chow, Ven Te, Ph.D, Open Channel Hydraulics, McGraw-Hill Book Company, 1959.
17. United States Dept. of Agriculture, Soil Conservation Service SCS National Engineering Handbook Section 4 Hydrology NEH-Notice 4-102, August 1972.

18. United States Dept. of Agriculture, Soil Conservation Service, Somerset, N.J. Urban Hydrology for Small Watersheds, Technical Release No. 55, January 1975.
19. United States Dept. of Commerce Weather Bureau, April 1956 Hydrometeorological Report No. 33, Washington, D.C.
20. United States Dept. of Interior, Bureau of Reclamation Design of Small Dams Second Edition 1973, Revised Print 1977.
21. Wolfe, P.E., 1977, The Geology and Landscapes of New Jersey, Crane, Russak & Company, Inc., New York, New York, 351 pp.

DRAWINGS

1. D-1 Plan of Dam, Sections & Details, by Dept. of Treasury, Div. of Building and Construction, State of New Jersey, dated 18 August 1975.
2. D-2, Elevations Sections & Details, by Dept. of Treasury, Div. of Building & Construction, State of N.J., dated 18 August 1975.
3. D-3, Topographic Survey (Partial) & Cross-Sections, by Dept. of Treasury, Div. of Building & Construction, State of N.J., dated 2 Sept. 1975.
4. Dwg. No 47, Elevation and Sections of Dam, by Morris Canal & Banking Co., Dover, N.J. Office, dated 19 Aug. 1924.
5. Dwg. No 44, Plan of Dam, by Morris Canal & Banking Co., dated 16 Aug. 1924.
6. Dwg. No 54, Plans & Sections of Gate Chamber, by Morris Canal & Banking Co., dated 22 Aug. 1924.
7. Dwg. No 33, Details, Morris Canal & Banking Co., dated 22 Aug. 1924.
8. Dwg. No 55, Change at M.C. Bridge #60 Roxbury Twp., by Morris Canal & Banking Co., dated 23 Aug. 1924.
9. Dwg. No 55A, Change at M.C. Bridge #60 Roxbury Twp., by Morris Canal & Banking Co., dated 23 Aug. 1924.
10. Dwg. No 56, Plans of Gatehouse, by Morris Canal & Banking Co., dated 26 Aug. 1924.
11. Dwg. No 57, Details of Fountain and Mill Outlet, by Morris Canal & Banking Co., dated 25 Aug. 1924.
12. Dwg. No 45, Location Map showing Work at Lake Hopatcong, by Morris Canal & Banking Co., dated 18 Aug. 1924.

13. Dwg. No 1/2, Repairs to Dam, by Dept. of Environmental Protection, Div. of Purchase & Property, Dept. of Treasury, State of N.J., dated April 1970.
14. Dwg. No 2/2, Repairs to Dam, by Dept. of Environmental Protection, Div. of Purchase & Property, Dept. of Treasury, State of N.J., dated April 1970.
15. Dwg. No AB-1, As Built Dwg. of Repair Work at Hopatcong Dam, by Dept. of Environmental Protection, dated 18 January 1971.

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